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Contents

1 Acronyms

ACIAR	Australian Centre for International Agriculture Research
AI	Artificial Intelligence
CA	Conservation Agriculture
CAAF	Conservation Agriculture Appraisal Framework
CASI	Conservation Agriculture Sustainable Intensification
CIAT	International Center for Tropical Agriculture
CIMMYT	International Maize and Wheat Improvement Center
CSA	Climate Smart Agriculture
CSIRO	Commonwealth Scientific Industrial Research Organisation
EI	Ecological Intensification
FACASI	Farm Mechanisation and Conservation Agriculture for Sustainable Intensification
FEW	Field Extension Worker
GIS	Geographical Information System
ISFM	Integrated Soil Fertility Management
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
MDAs	Ministries, Departments and Agencies
NARI	National Agricultural Research Institutes
NARO	National Agricultural Research Organisation
NAADS	National Agricultural Advisory Services
NGO	Non-Governmental Organisation
ODK	Open Data Kit
PAUF	Process of Agriculture Utilization Framework
PELUM	Participatory Ecological Land Use Management
PPPs	Public, Private Partnerships
REDS	Rural Enterprise Development Solutions
SACCO	Savings and Credit Cooperative Societies
SI	Sustainable Intensification
SIMLESA	Sustainable Intensification of Maize-Legume Systems for Food Security in Eastern and Southern Africa
ULN	Uganda Land care Network
UNBS	Uganda National Bureau of Standards
URA	Uganda Revenue Authority
UQ	The University of Queensland
ZimCLIFS	Integrating Crops and Livestock for Improved Food Security and Livelihoods in Zimbabwe
ZARDI	Zonal Agricultural Research and Development Institutes

2 Acknowledgments

The authors thank the various farmers and stakeholders in both Lira and Nakasongola districts and non-farm stakeholders for their time and willingness to participate in the field surveys, and the team of enumerators (Joselyn Kashagama, Latifah Namutebi) and field support staff (Joel Wakibi, Wilson Katamba and Peter Abila) who navigated the team in the field during the study. We also acknowledge the assistance rendered by Dr. Peter Kisakye in the analysis of the data. Andy Hulthen (CSIRO) prepared the survey tools and data and the maps presented in the report. Many thanks to the people who attended and participated in the stakeholder workshop in Kampala.

This study has been approved by CSIRO’s Social Science Human Research Ethics Committee in accordance with the National Statement on Ethical Conduct in Human Research 2007 (Updated 2018) (project 123/23).

3 Executive summary

There have been many research studies examining the potential benefits to adoption of a diversity of practices that improve soil health and water use efficiency in smallholder crop-livestock systems of East Africa. Conservation Agriculture (CA) includes principles around soil protection (with the use of retained stubble), strategic tillage, diversification of crops, and input management. There have also been many studies documenting the challenges to CA adoption that include the need for appropriate machinery and infrastructure along the commodity value chains, and the trade-offs between retaining crop residue as mulch and removing it as fodder to support livestock. In this project we reviewed the current landscape in terms of CA adoption and research in East Africa, with a focus on Uganda. We conducted interviews with stakeholders in Uganda and Australia (14 discussions), conducted surveys of farmers in two districts (Lira and Nakasongola, total of 62 people were interviewed, 26 for qualitative interviews and 36 for the quantitative interviews, both men and women farmers), reviewed the published literature, identified activities by funders and development partners, and conducted a workshop with stakeholders in Kampala (27 participants) to synthesize many people's perspectives. Our objective was to identify the research gaps that might be addressed with targeted funding in the future and enabled through identification of research partners in the region and Australia.

Much has been achieved over the previous 10 years in terms of increased awareness of the potential benefits of adoption of CA practices in several institutions and by farmers. In Lira 100% of respondents previously practiced CA to some degree, and many of the respondents used these practices on all their land, without modifications. In contrast, in Nakasongola 95% previously practiced CA to some degree, but only on parts of their land, and with a high degree of modification. There are some leading farmers using multiple CA practices and realizing benefits with over half of the farmers we surveyed having used CA practices in some way for four seasons. If we assume it takes three years to trial and adopt certain practices, many of these leading farmers are well along the transition pathway to CA adoption at significant scales. The legacy of historical initiatives and projects in this region is that there is high awareness and high adoption of some CA practices given the short time frame. For example, the Sustainable Intensification of Maize-Legume Systems for Food Security in Eastern and Southern Africa project (SIMLESA) examined the greater use of maize-legume intercropping systems to improve productivity including the use of permanent planting basins and other CA practices.

Some of the CA practices are part of traditional farming practices and well aligned with the current farming systems. Others are challenging to adopt for a diversity of reasons, and we documented dis-adoption of some practices. There are also frustrations due to the lack of quality inputs, insufficient capacity to train many farmers, the inaccessibility and cost of machinery farmers are asking for, issues that may reflect soil fertility decline, and high labour requirements for practices farmers know are important (e.g. permanent planting basins and mulching). SIMLESA and related activities have built a strong foundation for further scale out of practices in Uganda but scale up at the same time is necessary to overcome some of these challenges (which can't be addressed by focussing only on the farm-level). As an example, farmers reported that the cost of labour required to undertake some CA practices especially mulching and minimum tillage was high. To mulch one acre of crop land, 33% in Lira and 57% in Nakasongola reported it required 1-20 hours while others mentioned it took over 21 hours (67% in Lira, 43% in Nakasongola). Besides, respondents reported they needed to mulch either once per season (67% in Lira, 100% in Nakasongola) or two or more times (33% in Lira, 0% in Nakasongola) to see benefits. Generally, this was considered costly for many of the respondents and was compounded by the scarcity of mulching resources in some areas.

The challenges to improved crop and livestock production identified in our study are many and include lack of access to quality inputs, cost of inputs, access to machinery, agripest management for crops and livestock, lack of water, shortage of land, affordability of post-harvest storage facilities, access to markets, and farm labour issues. No single project or investment can address all these challenges at once, however there are clear drivers for change at national, and international levels, that could be catalysed further through project-level investments. The enthusiasm for Climate Smart

Agriculture and the need to adopt sustainable agricultural practices all support a greater emphasis on CA, and continued use of CA practices in areas where progress has already been made.

We conclude from the findings of our study that:

We need to **determine how to address the short-term costs of adoption of CA practices** to enable more farmers to maintain practices long-term. Whilst many farmers reported a desire for subsidized inputs, other factors like labour-saving incentives should also be considered. Understanding the causes of and addressing **declines in soil fertility under existing CA systems** is high priority if we want to reduce the risk of dis-adoption. Uncovering the nature and extent of productivity declines is a challenging area. We need to **support capacity to modify practices to local needs and economic realities.** This is especially the case for the development and use of a diversity of machinery where there is not a one-size-fits-all solution to be deployed. Extension systems must be built to encourage and enable modification, and experience-based learning, rather than disseminating packages of practices with rigid methods. **Innovation Platforms are useful for enabling CA adoption,** but we need to allow them to change, grow, dis-band and evolve through time after a project is complete. Integrating Innovation Platforms with demonstration sites and farmer knowledge exchanges means their influence extends beyond the immediate participants and can be hard to measure.

Our recommendations are that the focus of future research could shift in two divergent streams at very different scales:

1. **Methods to scale-out the adoption of CA practices in new regions with appropriate agroecologies**
   - Modelling and *ex ante* assessment at national levels using the ADOPT tool or similar approach to map the areas of potential benefit for certain practices.
   - Upscaling the Innovation Platform approach and expanding to new regions.
   - Research on the initial short-term economic and resource costs of CA practice adoption and how to incentivise.
   - Working with national and regional policy initiatives (and development partners) to scale-up CA practices and supports to encourage adoption.

2. **Research to improve the sustained long-term adoption of CA practices in farming communities**
   - Research on the cause behind, and how to halt, soil fertility declines in CA systems, circularity of nutrients in small-holder systems and use of organic manure and inorganic fertilisers.
   - Greater understanding about how to integrate livestock at the farm-level in CA systems through the movement and use of manures and mulches.
   - Research on durable weed and disease management in CA systems. Our farmer surveys continually identified pest and disease management challenges (for both crops and livestock) beyond weeds, but this was seen as the most critical group for CA adoption, and there is a gap in capacity in this research area.
   - The use of newly developed Innovation Platforms to enable access to high quality inputs (seeds, fertilisers, pesticides). Bringing rural input suppliers into the IPs to learn about CA and develop incentives for them to supply high quality inputs for certain practices.
   - Working with national and regional governments to support transitions to appropriate mechanisation.

The former stream (1) is focussed on bringing greater awareness of CA practices to new regions, and the latter (2) working in communities who already have some practice change occurring, but new challenges will impact sustained adoption. Both could include the use of modelling and foresighting, demonstration farms, case studies and dissemination of newly developed communication tools. Participatory research designed with, and tested by, farmers and farming communities was seen as critical to success in both streams.

Whilst we have focussed on Uganda in this scoping study, the two streams above may also apply and be relevant to other countries in East Africa.

4 Background

Many initiatives are trying to increase productivity in small-holder farming systems through the development and adoption of technologies and practice change. Their collective goal is to increase household food, nutrition, and income security for both urban and rural families. Importantly, the drivers of household food insecurity are becoming better understood and they don't only relate to the type and magnitude of food, fibre and livestock produced in a region or country. Frelat et al. (2016) examined indicators of food availability from over 13,000 households across 17 countries in sub-Saharan Africa. Crop production contributed 60% of food availability and off-farm income contribution ranged from 12-27% of food availability. Household size, number of livestock and land area could be used to predict food availability, but these relationships were influenced by distance to markets. This implies that agricultural development cannot simply focus on production constraints at the farm-level but must also understand institutions, markets, historical entitlements, social dimensions, and the diversity of contexts that small-holder farmers operate in today. Different solutions will be needed for people in different contexts and packages of technologies and practices that farmers can adapt for their circumstances are required.

The diversification and integration of farming systems could potentially increase household resilience to shocks, improve sustainability through the circularization of farm resources, and potentially increase profits. However, achieving diversification and integration at scale, especially in rainfed systems is challenging in small-holder systems in low- and middle-income countries and large-scale farms in high income countries (Fig. 1, Adhikari et al. 2023). Trade-offs are common, some practices take many seasons to deliver benefits and mistakes can lead to large losses and dis-adoption of practices. The adoption of Conservation Agriculture (CA) practices exemplifies this problem. Conservation Agriculture focusses on improving soil health through principles to protect soil (with the use of retained stubble or mulch), strategic tillage (or no tillage), and diversification of crops and crop rotations. CA can be part of sustainable intensification programs and is seen as a viable climate change adaptation strategy (see definitions below) (Jat et al. 2020, Bellotti & Rochecouste 2014). However, adoption of a complete package of practices has proven challenging in some contexts.

Multiple past projects, most notably, Sustainable Intensification of Maize-Legume cropping systems for food security in Eastern and Southern Africa (SIMLESA), led by the International Maize and Wheat Improvement Centre (CIMMYT) have shown the potential multidimensional benefits of the adoption of CA practices in Eastern and Southern Africa. The SIMLESA program was established in 2010 to sustainably increase the productivity of maize farming systems by 30% (by 2023) in each target country in eastern and southern Africa, and at the same time reduce seasonal down-side production risks. After successful implementation of the first phase (2010-2013), the program was extended for four years (2014-2018) with an increased focus on up-scaling of sustainable intensification technologies and renewed focus on crop-livestock interactions (Wilkus et al. 2021). This and aligned projects can be linked to impact on farms but not adoption of a complete CA package by as many farmers as could benefit from CA (i.e. scale out has only just commenced). The adoption process remains complex for smallholder farmers, with challenges associated with extension of complex practice change, mechanisation, and the management of livestock. In labour-limited systems, mechanisation is a requirement for efficient crop planting with no till or minimum tillage. Preserving soil cover by conserving crop residues conflicts with farmers need for fodder where livestock is a key component of the farming system. Layered on top of this are challenges associated with adoption of improved farming practices in general, like accessing high quality seed, fertiliser and pesticides, and access to markets. Other historical initiatives like ZimCLIFS, FACASI and Adoption Pathways have also contributed to the changes we see on the ground today.

The SIMLESA program in Uganda started later (2012/13) than other target countries and addressed the need to identify appropriate CA practices and support uptake and adoption in two contrasting regions, Lira and Nakasongola with significant soil compaction issues and bare ground. The research team focussed on compatible maize-bean intercropping, permanent planting basins, rip-line tillage and the use of improved seed and fertiliser (Wilkus et al. 2021, chapter 19 by Mubiru et al.). Post-harvest storage systems for maize and other products were developed to increase the ability of farmers to sell at a high price, and two innovation platforms were established in Uganda.

Many research studies have explored the reasons behind the lack of adoption of CA in certain contexts (e.g. Brown et al., 2019). The reasons fundamentally relate to constraints on smallholder farmers or reflect specific requirements for benefits to accrue to the adopters. There are constraints identified in relation to farmers financial and labour resources, and broader institutional constraints associated with facilitating the adoption process (Brown et al., 2017a). Lack of access to extension services and practice change information, to pesticides (especially herbicides), to improved seed and fertilisers, to alternative feed for livestock, and to machinery have all been identified (Tsegaye et al., 2015, Brown et al., 2018a,b,c,d).This has led some to recommend a transitional approach where farmers successively build on each practice (Brown et al., 2019) or a packaging of CA practices into a unit to be adopted as a whole system change (Thierfelder et al. 2018). In this scoping study, we examined the current challenges facing Ugandan small-holder production systems, and asked stakeholders for their perspectives on what needs to be done to enable adoption of CA practices. These perspectives vary slightly from what we see in the scientific literature as we have placed emphasis on the heuristic knowledge of stakeholders (built over many years of study and lived experience). Rather than thinking about an optimal future state, discussing how we can practically enable change of practice based on the goals and aspirations of small-holding farming households, and what resources are needed to achieve this is crucial.

Definitions and relationship between CA, CASI, CSA

There is a diversity of terms for collections of practices that if adopted by farmers, communities and countries simultaneously aim to increase production of food, reduce environmental and social costs, and improve resilience of agri-food systems to global threats like climate change. In this project we have used a broad definition of CA for the purposes of this study which includes principles around soil protection (with the use of retained stubble or mulching practices), strategic tillage (or no tillage), and diversification of crops. Livestock is integral to the application and contextualization of each of these principles especially regarding the use of manures and crop residues. When speaking with stakeholders in Uganda we often use the term “Conservation Farming” which has been used to describe some of these practices (it does not necessarily depend on adoption of all practices) and is more relatable. We list some related terms below but note these are all complementary to some degree and often encompass the same practices or packages of practices.

Conservation Agriculture Sustainable Intensification (CASI, Islam et al. 2019) focusses on using practices associated with CA to increase productivity in existing farming landscapes. Noting that successful CA adoption often relies on the use of quality seeds, fertilisers, and pesticides.

Sustainable Intensification (SI, Pretty et al. 2018, Wilkus et al. 2022, Piemontese et al. 2022) is an approach using innovations (new crop varieties, pesticides, and fertiliser) to increase productivity on existing agricultural land with positive environmental and social impacts.

Ecological Intensification (EI, Tittonell 2014, García-Palacios et al. 2019) focuses on ecological processes in the agroecosystem and emphasizes a systems approach and strongly considers social and cultural perspectives. This term is used more in a research context than in conversations with stakeholders.

Climate Smart Agriculture (CSA, Descheemaeker et al. 2016, Thornton et al. 2018) focuses on approaches, policies, and interventions to reduce climate stress, and enable adaptation and mitigation. CA could be considered a climate smart agriculture approach; however, it could also include practices like agroforestry and beekeeping.

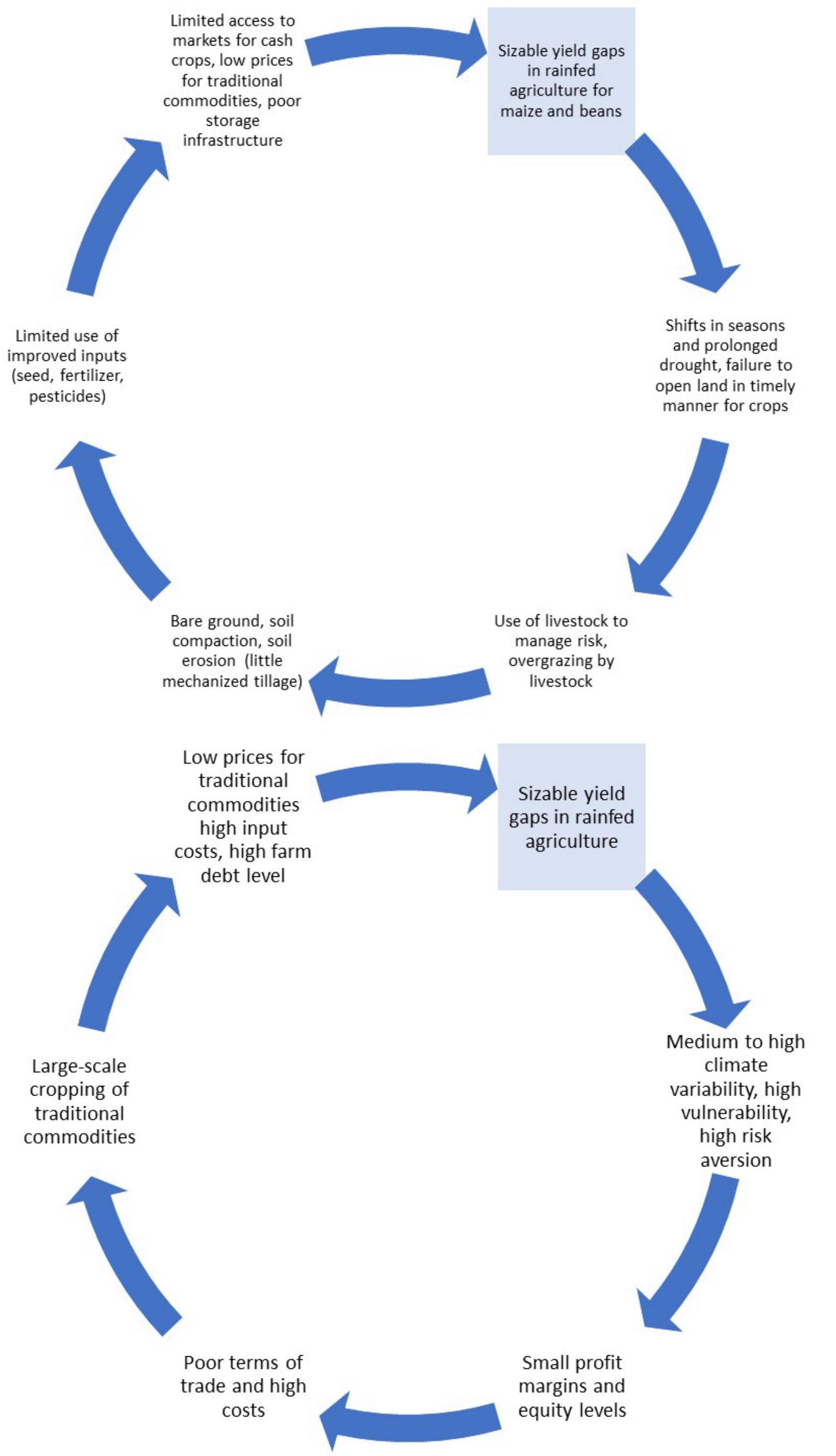

Fig. 1. The interacting drivers behind lack of incentives and opportunity to diversify rainfed cropping systems in Uganda (top) and Northern Australia (bottom). The bottom figure is taken from Wilkus et al. 2018 (chapter 13 by Rodriguez) and the top figure adapted from Mubiru et al. (2017).

5 Objectives

The identification of crop-livestock interactions is a challenge that has already been identified in relation to CA adoption. In this project, we will be attempting to identify where changes may have benefits for farmers should the right incentives and support mechanisms be in place. Our objective is to identify the research gaps that might be addressed with targeted funding in the future and enabled through identification of potential research partners in the region and Australia. Our research (which includes a literature review, farmer surveys, and interviews with stakeholders from soil health, farming systems, and livestock management fields) was guided by three research questions:

RQ1. Can we identify a transition pathway that has led to the successful adoption of CA practices to some degree in Uganda?

RQ2. In cases where we do not observe successful adoption of CA to some degree, can we identify the challenges that prevented/stalled integration into the existing farming system?

RQ3. Where do stakeholders see opportunities for greater/more appropriate crop-livestock interactions in their farming systems?

We used a survey to establish the current state of awareness, and adoption of CA practices by smallholders in target regions of Uganda.

- How much do farmers know about CA?
- What is their assessment of the potential benefits for their farming systems?
- How much do they practice components of CA?
- What is their assessment of the actual benefits accrued by practicing CA?

Understand the obstacles to adoption of CA.

- In what systems will CA benefits be compelling motivation for practice change (and what is inhibiting adoption in these systems)?
- What is the need for mechanisation for crop establishment, weed management, harvesting, produce processing and storage?
- How much are crop residues needed for feeding livestock during years with different seasonal conditions (I.e. a good year versus a bad year)?

Identify the research needs to address the obstacles.

- What could a research project explore to co-design with farmers practical options to allow them to capture the benefits of CA? Farmer-to-farmer learning may be one way to bring about change.

6 Methodology

Ethics and literature review

We conducted a literature review on CA practices in East Africa and focussed on articles concerning challenges with adoption and the process of technology adoption. We did not complete a full review of all the SIMLESA documents we read as this is a significant body of work. We did refer to some of the country-level summaries that have been published in the literature. We developed a document for human ethics approval detailing the scope of the project, how we would engage stakeholders, what information we would collect and how this would be kept private. The ethics approval included a draft list of questions for structured interviews with researchers, stakeholders, and farmers. The ethics approval was granted subject to some minor changes to the initial statements.

Region selection

The study was focussed on Uganda with survey work conducted in two districts, Lira district in the north, and Nakasongola district in the central part of Uganda. The two districts were selected as they were used in the previous SIMLESA project and have contrasting agricultural activities (Table 1). Although agriculture (crops, livestock, and fisheries) is an important activity in the two districts, Lira district is largely crop-oriented while Nakasongola is livestock-oriented (Fig. 1). Within the two districts, we also selected two sub-counties to undertake this study (Kalongo and Wabinyonyi in Nakasongola district, and Aromo and Lira in Lira district) the two representing low- and high production potential areas (Mubiru et al. 2017). Soils and other information were gathered about these regions. Soil fertility and health is an already identified issue in both regions, although the exact nature of this problem is not always well described. Bare ground coverage in Nakasongola, due to extreme cases of soil compaction, was 187 km2 (11%) of the 1,741 km^2 of arable land (Mubiru et al. 2017).

Table 1. Descriptive statistics of each district in Uganda.

	Lira	Nakasongola
Area	1,329 km^2	3,510 km^2
Annual rainfall	1,340 – 1,371 mm. One long dry season of about 4 months, from mid-November to late March.	875-1000 mm, long dry season of up to 5 months.
Agroecological zones	Northwestern Savannah grasslands.	Pastoral Rangelands.
Major crops	Cassava, beans, millet, maize, sweet potatoes, sim sim, soybeans, sunflower, cotton, sorghum ground nuts, and rice.	Maize, bananas, cassava, beans, a host of vegetables and fruits (tomatoes, watermelon, African eggplants, leafy vegetables), coffee and vanilla. Mango in Southern parts.
Major livestock	Poultry (25%), pigs (3%), cattle (45%), goats (40%) Fish (2-5%).	Poultry (70% households), pigs (56%), cattle (52%), goats (37%). Fish wild harvest from lakes.
Challenges from the literature	Prolonged dry seasons, declining soil fertility.	Drought, poor soil fertility and bare ground, deforestation.

Reference: NARO-FAO report, Integrating climate resilience into agricultural and pastoral production in Uganda, through a Farmer/Agro-pastoralist Field School Approach – GCP/UGA/043/LDF Project. Assessing and mapping natural resources and the main agrarian systems in Nakasongola District.

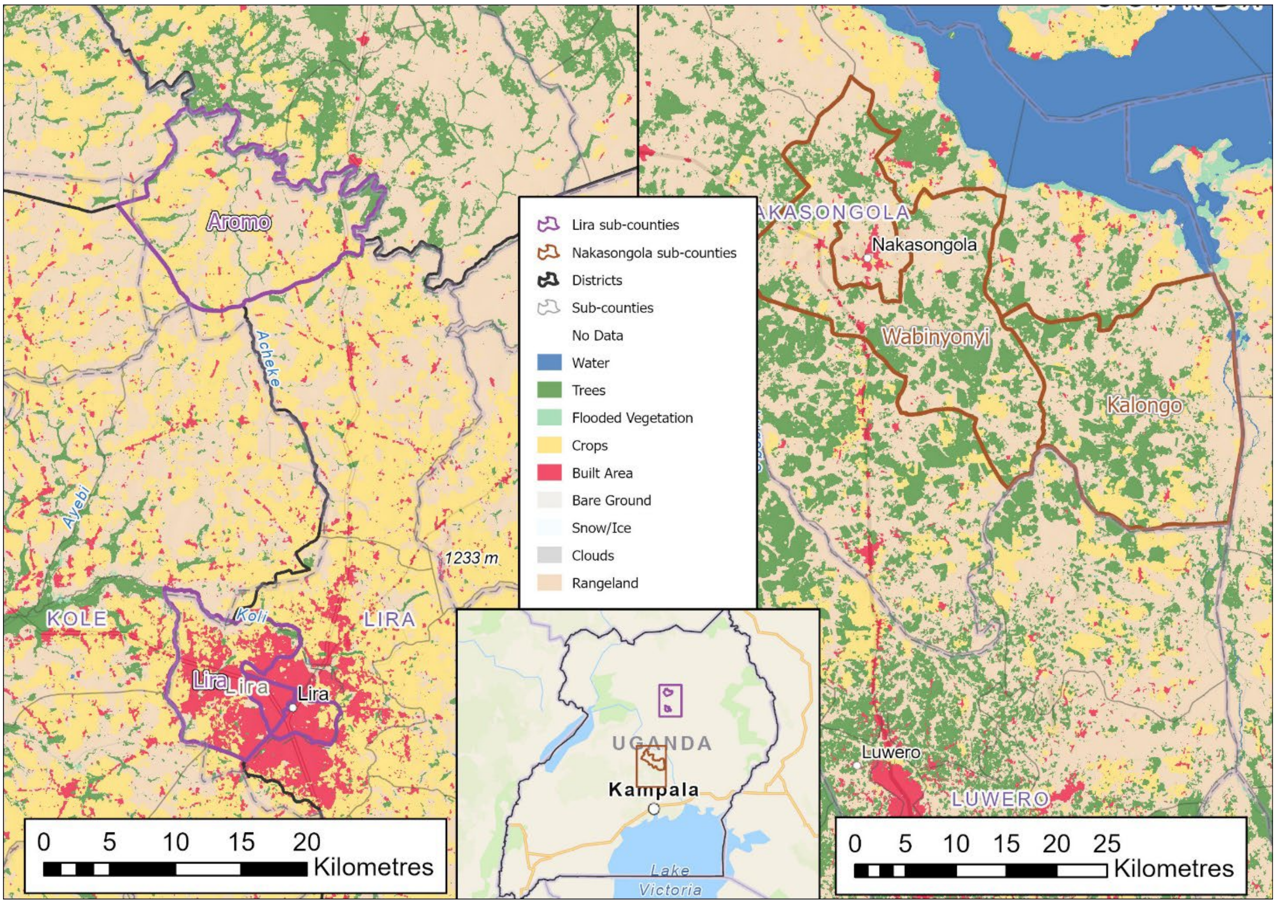

Fig 2. Land use and land cover in each of the districts in Uganda. Sentinel-2 10m land use/land cover maps. Land use is classified using a deep learning Artificial Intelligence (AI) land classification model (Karra, Kontgis, et al. 2021).

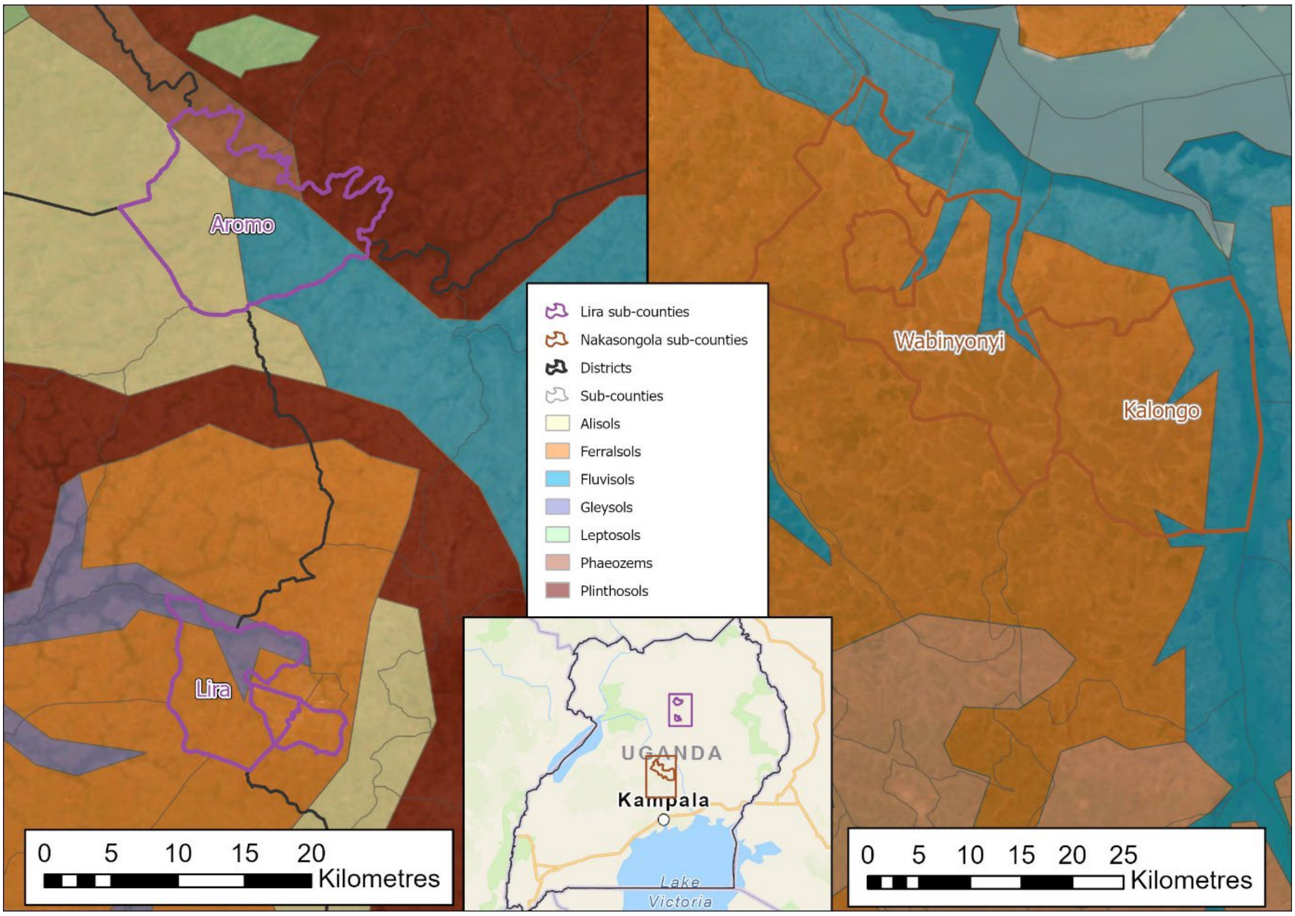

Fig 3. Soil maps of the districts in Uganda. Dominant World Reference Base Soil Group of survey regions. Extracted from the Soil Atlas of Africa (https://doi.org/10.1016/j.geoderma.2013.07.007).

Surveys of farmers practices and challenges, including the value chain

Sampling procedure and data collection

Within the sub-counties, sampling was undertaken at two levels targeting respondents who had been exposed to CA (former SIMLESA beneficiaries) and those who had not been exposed to CA technology (non-SIMLESA respondents). The purpose of this was to understand whether people exposed to CA technology were still practicing it (to appreciate the benefits of CA technology) and if they were not practicing what challenges/obstacles they faced, and what they thought was needed to address the challenges as well as the opportunities they envisaged in the future. By using non-SIMLESA respondents, we also wanted to understand if there are people who have adopted CA technology from elsewhere or who have practiced CA technology on their own without having been part of a previous CA project.

Qualitative and Quantitative surveys

To investigate the benefits and challenges of practicing CA technology, we conducted two kinds of stakeholder surveys (an in-depth qualitative survey and a quantitative survey) using questionnaires administered during face-to-face interviews with stakeholders (Fig. 4, Fig. 5). The questionnaires were structured (see Appendix 1) and were pre-tested to assess suitability by enumerators prior to use in the field. The questionnaire time to completion averaged about an hour.

The list of stakeholders for this study was quite diverse to include as many a number across the commodity value chain and included farmers, processors, district local government (production/extension/commercial officers), input dealers, buyers-aggregators of produce, agricultural innovation platform managers as well as policy makers. A total of 62 stakeholders were interviewed -26 for the in-depth (qualitative) interviews and 36 for the quantitative interviews (Fig. 5).

The attributes investigated during the study included among others; stakeholder socio-economic characteristics such as age, gender, education levels, household income, knowledge/practice of CA technology, crop production profiles-crops, farm size, yield and reasons for observed production, implements used, cover crops, labour requirements for CA practices, livestock production profiles, grazing methods, pastures etc., challenges to crop/animal production, challenges/opportunities related to marketing, adoption levels and challenges/obstacles to adoption of CA practices, and stakeholder perceptions on CA and future opportunities. Data were collected using Open Data Kit (ODK, Hartung et al. 2010) mobile data collection software (ODK Collect) on predesigned electronic forms and which upon completion were uploaded to the cloud servers. We also supplemented the information from the interviews by field observations whenever it was possible.

Data analysis

We used Excel to code and track emerging themes in analysing qualitative data from in-depth interviews, while for quantitative data, Stata was used to generate proportions and establish bivariate relationships by districts and gender, and to compute chi-square statistics to test associations between variables.

Fig. 4. The enumerators conducting interviews in the field in Uganda.

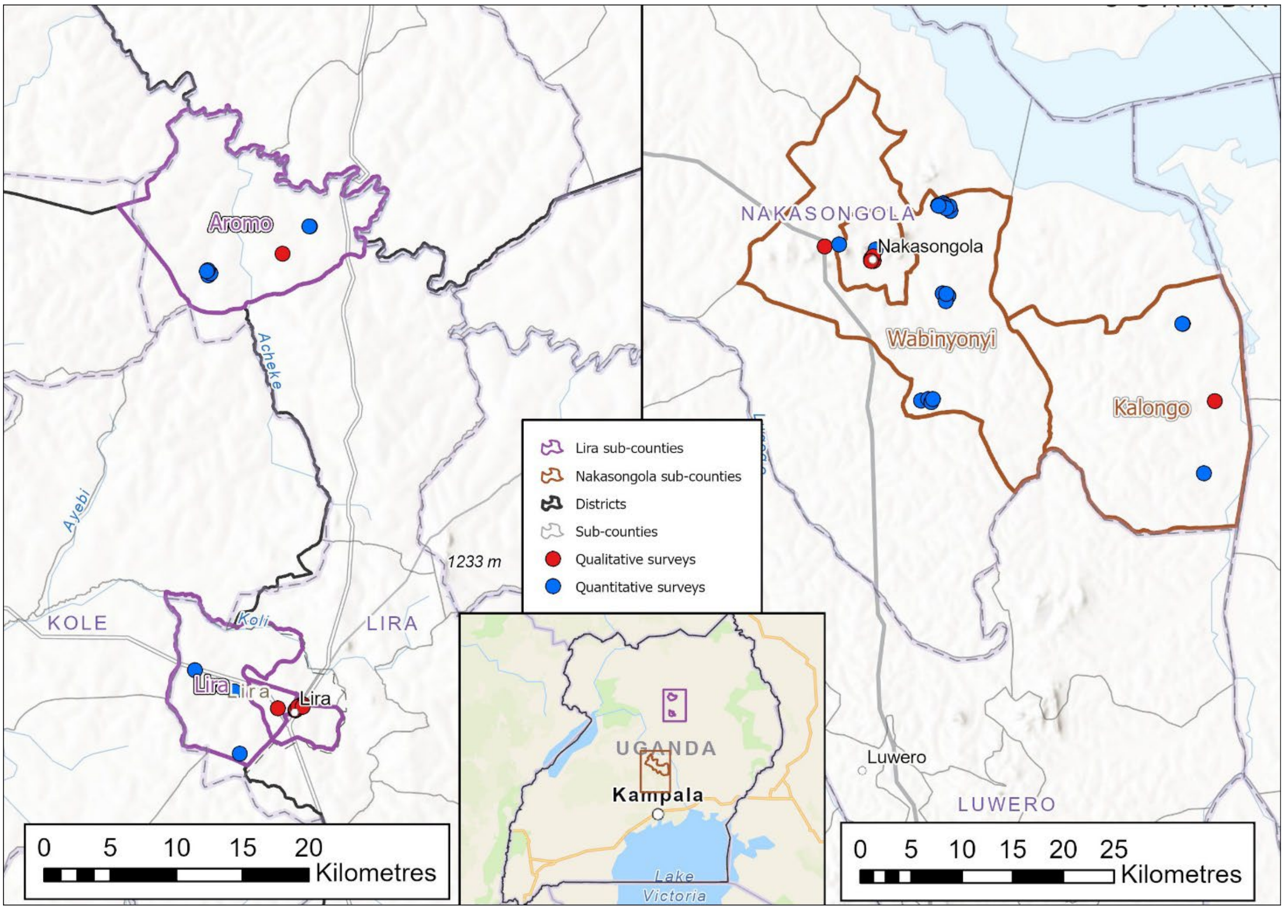

Fig. 5. Map of survey locations in the two districts in Uganda. The red dots illustrate locations where qualitative surveys were conducted, the blue dots the quantitative surveys about on-farm practices.

Qualitative structured interviews with other non-farm stakeholders

We conducted 14 structured interviews (Table 2) with stakeholders that were not located in the regions but had strong links to CA research, extension, and innovation (template in Appendix 1). These were researchers, policy makers, representatives from NGOs and development organisations, NARO staff, and key project leaders from SIMLESA or past projects. We asked them to identify a practice or area of research associated with CA that we could discuss in detail (usually an area they had technical knowledge), and then probed for the gaps and opportunities associated with that practice. We then asked questions about where they see the challenges and opportunities associated with CA more generally. We did not constrain the discussion and allowed people to explain where they say some of the biggest issues that need to be addressed are.

Table 2. People we conducted a structured interview with to ask about their perspectives about challenges and opportunities associated with CA adoption in Uganda (and in some cases East Africa more broadly).

Stakeholder	Location	no. people
Policy maker	Uganda	4
Researcher	Uganda	1
Researcher	Australia	4
Network leader	Uganda	2
Land manager	Uganda	3

Stakeholder workshop

A workshop was held in Kampala on the 22nd November 2023 to provide feedback to stakeholders about what we found during our survey work and to gather more information from them about the challenges and key gaps in relation to CA adoption. In total we had 27 participants from NARO, research organisations, policy makers, district extension officers and representative farmer leaders from Lira and Nakasongola districts. We invited two external experts; Dr. Mekuria Mulugetta (ex-leader of SIMLESA) to present on the broader context of CA across East and Southern Africa, and Dr. Jonathan Odhong (CIMMYT) to provide an overview of lessons learned about how to deliver impactful science research. Dr. Drake N. Mubiru provided an overview of the SIMLESA work in Uganda and Dr. Andrew Kalyebi presented a summary of the challenges to adoption of CA practices synthesized from the field surveys. These presentations generated discussion in the room before we broke into small groups. The participants were asked to work in small groups to identify activities they considered high priority to be addressed in the next five years. Some of these require more discussion around the details, but we asked participants to simply sketch out important activities based on the challenges discussed prior. These are detailed below.

Achievements against activities and outputs/milestones

No.	Activity	Outputs/ milestones	Completion date	Comments
1.1	Project commencement	Development of contract with ACIAR and sub-contracts collaborators. Develop and gain ethics approval. Recruit additional staff in Uganda.	29/02/2023 Ethics completed 30/06/2023	Completed as planned.
1.2	Planning and engagement	Plan the survey tools and online and offline data input systems. Review of soils data sets and mapping layers. Literature review.	30/07/2023	Completed as planned.
		Train enumerators and plan logistics for the survey.	30/07/2023	Completed as planned.
1.3	Delivery surveys	Qualitative survey non-farm stakeholders. Quantitative survey, on-farm stakeholders. Qualitative survey rural stakeholders.	1/08/2023	Completed as planned.
	Data analysis	Analyse the data. Synthesize the results. Start writing the report.	1/12/2023	Completed as planned.
	Synthesis	Combine the literature with the data gathered from the surveys.	1/12/2023	Completed as planned.
1.4	Stakeholder workshop	Held in Kampala on the 22nd Nov. 2023 ~30 stakeholders.	1/12/2023	Completed as planned.
	Synthesis	Combine all the data points and synthesize the results into report. Share draft report with others.	31/12/2023	Completed as planned.
1.5	Final report	Submitted to ACIAR for review.	31/01/2024	Completed as planned.

7 Key results and discussion

RQ1 Can we identify a transition pathway that has led to the successful adoption of CA practices to some degree in Uganda?

Through the field surveys we have identified people who have managed to successfully adopt one or multiple practices associated with CA, people who have trialled and dis-adopted certain practices (see RQ2), and people who have yet to trial CA practices in any way. Results of field surveys revealed that 73% of the respondents in Lira and 91% of those in Nakasongola were currently practicing CA to some degree (with greater proportions practicing at some time in the past). There was no significant difference between districts and between male and female in the proportions of those practicing CA. A smaller proportion in both districts (27% in Lira, 9% in Nakasongola) reported not to practice CA at all.

In our surveys, we examined the adoption processes of CA and individual practices. However, previous authors have noted that CA adoption requires a package of complementary practices, ideally implemented at once (Thierfelder et al. 2018). Between Lira and Nakasongola, the components of CA practiced by the respondents differed significantly between districts but there were no differences by gender. In Lira for example, 50% of the respondents reported to practice minimum tillage only, no farmers reported to practice only minimum tillage in Nakasongola. In Lira, 38% of the respondents practiced both mulching and crop rotation while 11% practiced both in Nakasongola. 13% in Lira practiced crop rotation only while it was 32% in Nakasongola. No farmers in Lira reported to practice a combination of crop rotation and minimum tillage while 32% did practice that in Nakasongola (Fig. 6). 21% of respondents in Nakasongola practiced all the three CA components (minimum tillage, crop rotation and mulching) while none practiced all three in Lira. The differences between Lira and Nakasongola by components of CA practiced were significant (P=0.02) but not by gender (P=0.7).

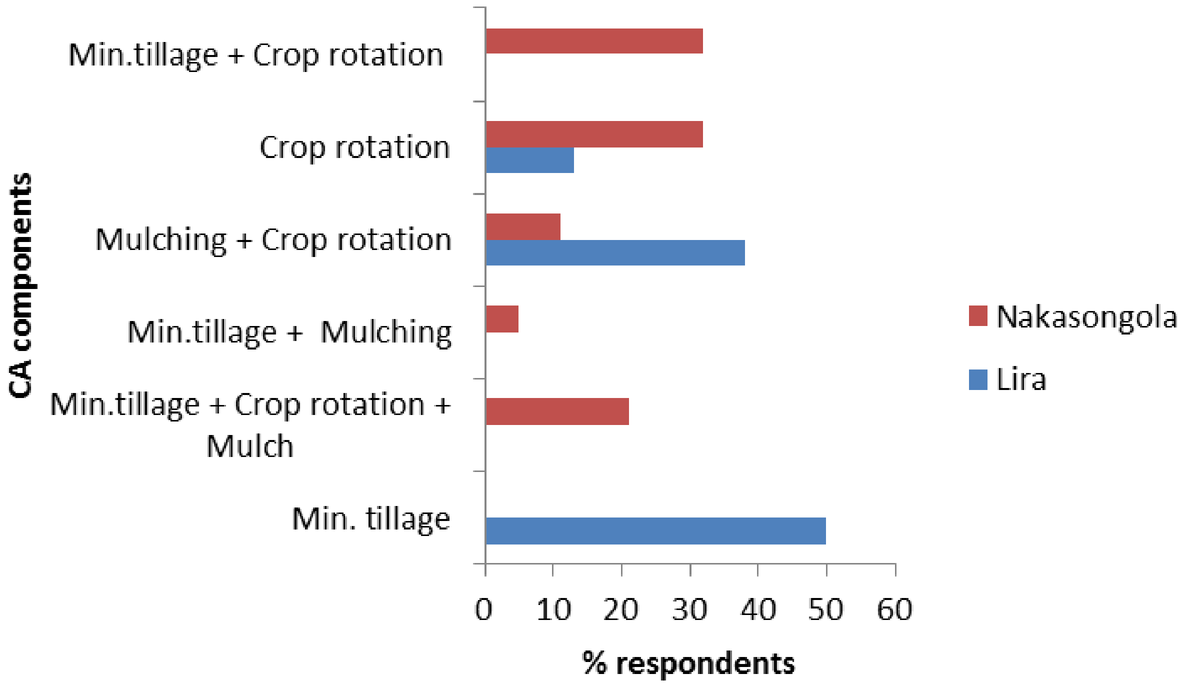

Fig 6. Proportion of respondents practicing different components/combinations of CA components in Lira and Nakasongola districts.

While most respondents in Lira and Nakasongola reported to grow the same types of crops under CA (maize, beans, ground nuts, soybeans), the proportions of farmers growing these different crops and combinations of crops differed by district but not by gender. For example, 64% of respondents in Lira and 35% in Nakasongola reported to grow maize and beans under CA, 36% grew maize, beans and soybeans under CA in Lira compared to 15% in Nakasongola. Whereas 25% grew maize, beans and ground nuts under CA in Nakasongola, this combination of crops wasn't reported grown under CA in Lira.

All respondents in Lira (100%) reported to have previously practiced CA compared to 95% that reported to have done so in Nakasongola. These proportions did not differ significantly between districts and by gender (95% of female and 100% male previously practiced CA). However, the crops previously grown under CA differed significantly between districts (P=0.03) but not by gender (P=0.47). While most farmers in the two districts reported to have started to use CA technology from 2015 (64% in Lira, 60% in Nakasongola), the time frames did not differ by district or gender (58% started to use CA in 2015). Some respondents especially female (5%) reported to have started to use CA technology since childhood, while 36% in Lira and 40% in Nakasongola reported to have started use of CA technology between 2012 and 2014.

On the frequency of use of CA technology over the last 2 years, 55% of respondents in Lira and 85% of those in Nakasongola reported to have practiced CA for 4 seasons, 27% in Lira and 15% in Nakasongola practiced for 1-2 seasons while 18% in Lira had practiced for all seasons (practiced every season). The frequency of use of CA was not different between districts and by gender. However, most male and female respondents reported to have practiced CA for over four seasons followed by those for 1-2 seasons (16% females, 25% males). Of the respondents that were interviewed in the districts, 70% of those in Nakasongola reported to know about the SIMLESA project compared to 50% from Lira.

Field surveys in both Lira and Nakasongola districts revealed that farmers have adopted a diversity of agricultural practices that promote sustainable and environmentally friendly farming to optimize crop production. Some of these practices are a core part of CA. These practices were;

- Use of herbicides to control weeds, the use of pesticides to control pests and diseases.
- Use of improved seeds with different desirable traits (such as resistance to pests/diseases, increased yields, adaptability etc.).
- Seed selection by farmers is practice that enables them to choose best quality seeds for planting.
- Use of intercropping to diversify crop types (maize & beans, banana & coffee).
- Planting crops in lines or rows.
- Use of organic manure (from poultry and animal manure).
- Use of inorganic fertilisers (such as DAP and Urea) to provide essential nutrients to crops and maintain soil fertility.
- Mulching for moisture retention in the soil.
- Use of proper post-harvest handling practices (such as drying on tarpaulins, using PICS bags, using grain storage cribs) to help maintain the quality of produce, reduce losses, and improve overall value and marketability.
- Use of machinery such as rippers to reduce soil disturbance and erosion for efficient and sustainable farming and returning crop residues to the soil as organic manure.

What does the transition pathway for CA adoption look like?

Based on the Process of Agriculture Utilization Framework (PAUF), an approach that seeks to understand the various stages of use (adoption) and non-use (non-adoption) (Brown et al., 2017b), we established the various levels of adoption. Our assessment was based on utilization as opposed to approaches that focus on intensity and modifications of CA and CA components (the Conservation Agriculture Appraisal Framework- CAAF).

Beyond the phase of exposure which involves farmers obtaining awareness and familiarity with the CA practices, we sought to assess how CA practices have been trialled on farms. We asked if practices were used on a restricted area of the farm, if practices were modified or adapted in some way, and what resources (money, time, knowledge, labour) were used to implement this change. If a practice was used on a portion of their land we defined them as semi-utilizers, or all their land as total utilizers. Using this approach, CA adoption among stakeholders was variable. While there were those who did not practice CA for lack of awareness, still others did not practice CA for other reasons beyond lack of awareness. In Lira 100% of respondents previously practiced CA to some degree, and relatively more people used these practices on all their land, without modifications. In contrast in Nakasongola 95% previously practiced CA to some degree, but only on parts of their land, and with a high degree of modification (Fig. 7). Respondents who reported to have practiced or are practicing CA using their own resources were 36% in Lira and 11% in Nakasongola, and those who practiced CA with assistance from subsidies from NGOs or other organisations were 64% in Lira and 89% in Nakasongola (Fig. 7). Subsidies were mainly on agro-inputs particularly improved seed, and sometimes herbicides. Subsidies enhance uptake of CA practices by overcoming challenges associated with access (lack of competition, high costs) and quality (lack of trust in supplies). At the different levels of adoption, there were no differences between districts, and between male and female respondents except among semi-utilizers there were more females than males and among total utilizers where the opposite was true (*P*=0.006) (Fig. 8).

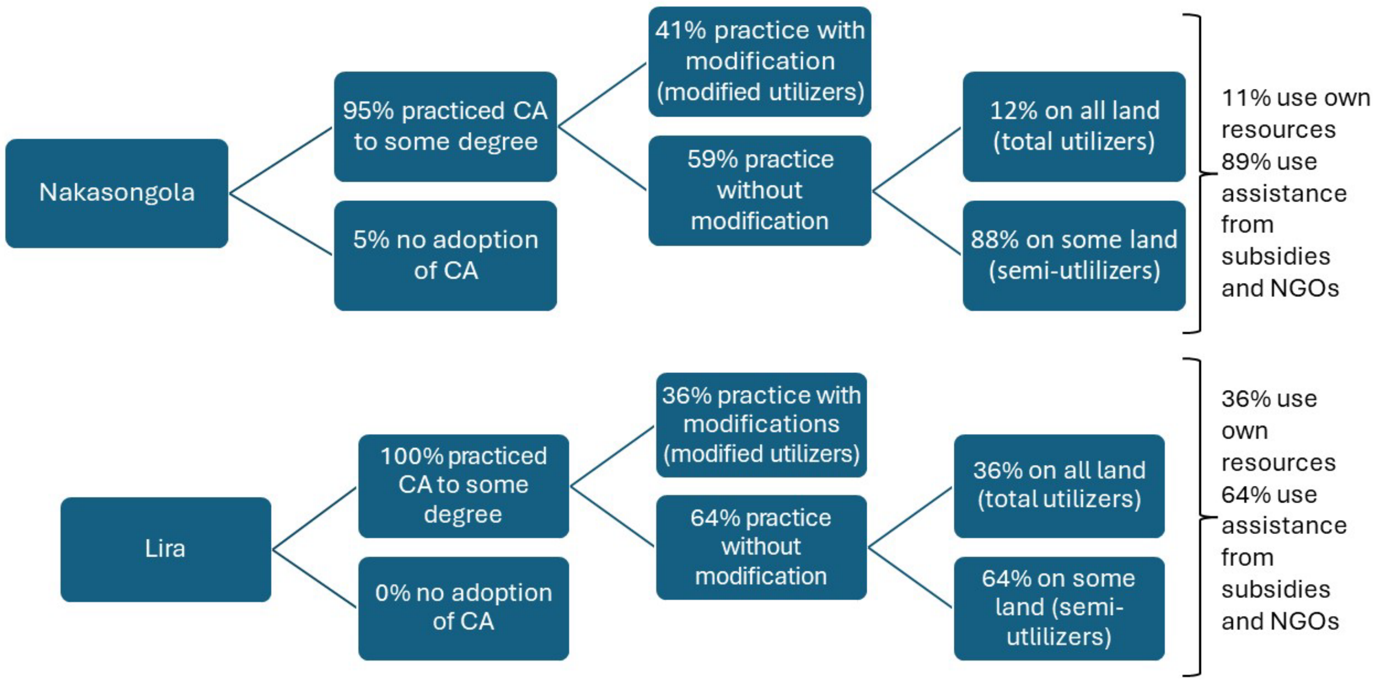

Fig. 7. Summary of the transition pathway for farmers who have adopted CA to some degree in each region in the past (and currently). These respondents are those that are aware of CA.

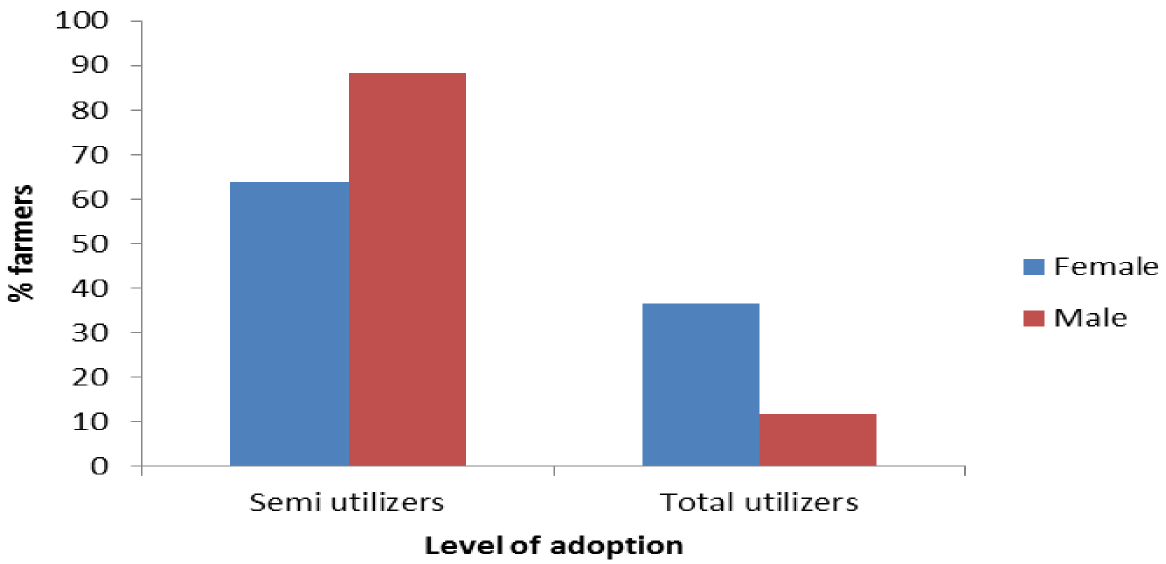

Fig. 8. Percentage of respondents/farmers by gender who practiced some CA practices based on area applied.

RQ2 In cases where we do not observe successful adoption of CA to some degree, can we identify the challenges that prevented/stalled integration into the existing farming system?

Biophysical challenges

Farming systems in Uganda (and across East Africa) face a series of challenges to improved agricultural productivity and household food security. Some of these are related specifically to CA or constrain adoption of CA practices, and some constrain adoption of any novel practice. For example, management of agripests (weeds, disease, insects) is a universal problem identified for crop and livestock production, but for CA adoption weed management is the key constraint. From our surveys we did not separate the findings discussed below according to those who had or had not adopted CA practices in some sense (our sample size is too low for a robust analysis) but do highlight the challenges currently constraining CA adoption and integration into farming systems.

Brown et al. (2017a) conducted an analysis focussed on farmers who negatively evaluated CA across 6 African countries including Uganda and found that the feasibility of implementation of practices and the resources needed to implement practices were the key issues. Surveys conducted in 2015 (Table 4) identified production issues such as agripest management, declining soil fertility and lack of good quality seed. In our 2023 surveys (Table 5) seed quality and agripest management were also identified by farmers. In both surveys the challenges identified are interlinked in complex ways and may not only represent a challenge for adoption of CA practices. For example, the shortage of land for grazing livestock and declining soil fertility for crops means that these production elements are in competition for land rather than integrated and complementary. The lack of reliable input supplies like herbicides (and the knowledge on how to apply them safely and effectively) directly impacts a farmer's ability to prepare land for cropping in a short time frame and with limited labour resources. In this context, the adoption of CA practices which require more complex management of weeds, intercropping (and associated change to soil fertility) and changes to when and how labour for land preparation is used on the farm can be infeasible for many farmers. In our survey we identified practices that had been trialled on farms and dis-adopted (Table 6). The reasons identified by the respondents for dis-adoption were often those that with the right modifications, training and extension support could have been overcome (e.g. through training farmers can learn to manage competition between crops seen during intercropping).

Table 4. Challenges faced by farmers along the maize–legume commodity value chains, Nakasongola and Lira (identified in 2015). Reproduced from Table 19.1 Wilkus et al. 2021.

Maize	**Legume**
Pre-production constraints (descending order of importance)	
Failure to open land on time shifts in seasons/ prolonged drought	Lack of good-quality seed
Poor-quality seed	Failure to open land on time
Lack of agro-input supplies	Lack of reliable agro-input supplies
Production constraints (descending order of importance)	
Weed infestation	Weed infestation
Crop damage by pests	Crop damage by pests
Declining soil fertility	Declining soil fertility
Crop damage by diseases	Crop damage by diseases
Post-harvest constraints (descending order of importance)	
Poor storage	Poor storage
Exploitative markets	Exploitative markets

Table 5. Top five ranked challenges to crop and livestock production in the two districts we surveyed in 2023.

Lira	**Nakasongola**
Crops	
1. Crop disease	Crop disease
2. Crop pests	Crop pests
3. Prolonged dry spells/drought	Prolonged dry spells/drought
4. Unpredictable seasons	Shortage of land
5. Low seed quality	Low seed quality
Livestock	
6. Prolonged dry spells/drought	Prolonged dry spells/drought
7. Loss of animals to disease	Loss of animals to disease
8. Shortage of food/feed for animals	Shortage of food/feed for animals
9. Lack of water for animals	Lack of water for animals
10. Shortage of land for grazing	Shortage of land for grazing

Table 6. Practices adopted and later abandoned by some individual farmers in Lira and Nakasongola districts.

Practice	**Reasons for dis-adoption**
Intercropping	Difficult to manage competition between crops
Ripper	Death of oxen Tractor made this practice obsolete Communally owned and sometimes inaccessible at key times Not locally available
Permanent Planting basins	Labour-intensive Delayed planting
Mulching	Hard to gather enough for larger areas of land
Line planting	Time consuming to establish lines
Herbicides	Too costly Not compatible with crops

Cost of labour and how this impacts adoption of certain biophysical practices

Farmers reported that the cost of labour required to undertake some of the CA practices especially mulching and minimum tillage was high, for example, to mulch one acre of crop land, 33% of respondents in Lira and 57% of those in Nakasongola reported it required on average 20 man-hours while others mentioned it required over 21 man-hours (67% in Lira, 43% in Nakasongola) (P=0.27). Besides, respondents reported they needed to mulch either one time in the season (67% in Lira, 100% in Nakasongola) or 2 times or more (33% in Lira, 0% in Nakasongola) for effective use. There were no differences between districts and between male and female respondents in terms of labour requirements (number of man-hours, and number of times required to mulch) in a season. Generally, this was considered costly for many of the respondents and was compounded by the scarcity of mulching resources in some areas.

Socio-economic issues

Access to inputs

Farmers reported they experienced various challenges which included not only poor access to quality inputs but also the high costs of these inputs. Others were poor storage for agricultural produce which resulted in marketing challenges for produce as well.

Farmers reported accessing inputs for use in CA from sources that included input dealers, fellow farmers, retail shops as well as public markets. Those that obtained inputs from input dealers were 27% in Lira and 48% in Nakasongola. Access from fellow farmers was a practice common in Nakasongola only (19%) but not in Lira. Retail shops and public markets constituted 18% of the sources from Lira and 10% in Nakasongola. There were no differences in means of access by both district and gender.

The distance from home to where farmers accessed inputs was highly variable but ranged between 0km and over 20 km. Most farmers were 0-9km from source (73% in Lira, 52% in Nakasongola), those between 10-19km were 9% in Lira and 38% in Nakasongola while those 20km and further were 18% in Lira and 10% in Nakasongola. For these distances, there were differences between districts for numbers of farmers accessing inputs (P=0.03) but not by gender.

Cost of inputs (seeds, pesticides, fertilisers)

The cost of inputs, particularly improved seeds and herbicides was frequently cited as a major challenge. Many farmers expressed concerns about the high cost of these inputs, with specific emphasis on the expensive nature of improved seeds (priced at 25,000 UGX per kg in Lira compared to a price of 7,500 UGX per kg in Kampala). Improved seeds often come at a higher price but offer better yields and crop resilience, making them an essential investment for CA adoption. The high cost of improved seeds is a financial burden that hindered many farmers from adopting CA practices effectively especially those with limited financial resources.

"*The practices are expensive for example, improved seeds are expensive (IDI, Male, Lira)".*

"*Costs of purchasing improved seeds are high (IDI, Female, Lira)".*

"There is increased labour and costs of purchase of improved seeds (IDI, Female, Nakasongola)."

The additional costs borne by the farmers reflect the financial challenges that they face when transitioning to CA practices. Managing these costs while maximizing the benefits of CA, such as improved soil health, increased yields, and reduced environmental impact, is a crucial aspect of successful adoption. Farmers may seek support and strategies to offset these expenses effectively through requests for subsidies from Government and partners. The project could not describe properly what looks like a failure of the market to deliver input at competitive price, but observed there is little competition between input suppliers in villages. Increased access to credit facilities (loans) that can help them access inputs and to develop reliable market and supply chains.

Quality of inputs, adulteration is an issue.

Several participants encountered difficulties in accessing quality herbicides, fertilisers, and improved seeds. Counterfeit products and expired inputs were mentioned, highlighting the challenge of obtaining genuine and effective agricultural inputs.

“Herbicides and fertiliser use is easy, but it is very difficult to access those of a good quality and farmers can only access those of good quality in Lira city only (IDI, Male, Lira).

Fake pesticides and seeds are on the market to the extent that sometimes farmers buy expired inputs (IDI, Male, Nakasongola)”.

Accessibility and cost of machinery (e.g. rippers)

Implements used for tillage in both districts included the hand hoes, ox-ploughs, and ox-drawn ripper. Farmers who used hand hoes constituted 36% in Lira and 33% in Nakasongola. Those who used ox-ploughs were 9% in Lira and 38% in Nakasongola. Other farmers integrated the use of hand hoes and rippers (27% in Lira, 10% in Nakasongola), while others used all the three-hand hoes, ox-ploughs and rippers (27% in Lira, 19% in Nakasongola). There were no significant differences in numbers of respondents who used these implements by district. While more females tended to use hand hoes compared to men (who tended to use ox-ploughs and rippers), these differences were not significant by gender,

In the future, 55% of the farmers desired to use a tractor in Lira, and 52% in Nakasongola. A few other farmers wished they could use ox-drawn implements for minimum tillage (27% in Lira, 24% in Nakasongola). Other implements desired for use in the future included rippers (10% in Nakasongola, none in Lira) and combined tractor and planters (9% in Lira, 5% in Nakasongola). The respondent’s desires for these implements were not different with respect to gender.

Besides access being a challenge, several respondents also highlighted the high cost of machinery (equipment and tools) for CA practices as a significant challenge. Engine spray pumps, manual spray pumps, and other machinery are necessary for tasks like spraying pesticides, reducing manual labour, and improving overall efficiency yet acquiring these tools can be a notable financial commitment. This financial barrier can make it difficult for some farmers to access and use the required equipment.

“Purchasing of herbicides, land preparation, buying improved seeds, labour for planting, weeding, spraying with pesticides due to pest attacks like the fall army worm (IDI, Female, Nakasongola)”.

“Buying some of the machines is expensive for some of the farmers to afford (IDI, Female, Lira)”.

“I stopped to use rippers because they were being distributed in groups and were owned by the group leaders who also don’t want to share them with the rest of the members. They are also not locally available (IDI, Male, Lira).”

Selling produce

Most farmers in the districts sold their produce either individually (64% in Lira, 95% in Nakasongola) or collectively in groups (36% in Lira, 5% in Nakasongola) and these differences were significant between districts but not by gender. Most markets for selling produce were located within 0-9km (100% in Lira, 91% in Nakasongola). Access to markets was predominately by motor vehicles (64% in Lira, 43% in Nakasongola) as compared to motor bikes (36% in Lira, 43% in Nakasongola). The means of access were similar between districts and did not differ by gender.

The produce was usually sold to traders (91% in Lira, 86% in Nakasongola), millers (9% in Lira, 10% in Nakasongola) and middlemen (5% in Nakasongola). Traders are large scale buyers of produce who own stores with the ability to buy in bulk. Traders can add-value or process the produce and they determine the market prices. Middlemen are the link (go-between) between the smallholder farmers and the traders. Middlemen buy in small units from the farmers and sell to traders after bulking. They maximise their profits by buying cheaply from farmers and taking the produce to the traders (who pay way more). The project attempted to interview traders but was unsuccessful in engaging them. Asymmetry of market information between traders, middlemen and farmers shapes their interaction.

All farmers in Lira were able to store their harvested produce on the farm prior to sale compared to 91% of those in Nakasongola. Gender was marginally significant for storage of produce with 100% of females being able to store their produce compared to 83% of the men (P=0.06).

The innovation system and institutions

The structure of Ugandan innovation system is important in the context of adoption of CA. NARO is made up of seven National Agricultural Research Institutes (NARIs) predominately focussed on research and development of farming technologies (both crops and livestock), and nine Zonal Agricultural Research and Development Institutes (ZARDIs) located in each agroecological zone focussed on the dissemination of research outputs. Makerere University (Kampala) and Busitema University (for mechanisation) have strong agricultural training and research presence. Generally, there are strong links between research outputs, and the scientifically derived local knowledge about what are the best farming practices to use, however the dissemination of these practices relies on the input supply and the extension systems.

The NAADS (National Agricultural Advisory Services) employs district agricultural extension officers located in each district (mainly for subsidised input supply currently). There are experts in livestock, forestry, and water in each district office. There are links between the organisations in Uganda through to the Consortium of International Agricultural Research (CGIAR) system, predominately CIMMYT, but with no office in Uganda. The International Livestock Research Institute (ILRI) (livestock), International Institute of Tropical Agriculture (IITA) (banana), and International Centre for Tropical Agriculture (CIAT) (beans) have hubs in Uganda. There are a series of NGOs and other actors (e.g. Rural Enterprise Development Solutions (REDS), Africa 2000 network) who provide training and services to farmers. Whilst the quality of the extension services is high, farmers rely mainly on in-person interactions with extension staff (which is valued highly). We heard that more time with extension officers was needed to embed practice change successfully on farm. Furthermore, the number of farmers that need assistance and the broad knowledge base needed for each extension officer is challenging.

It is common for farmers to be members of some sort of farmers organization or co-operative (in our survey 91% in Lira, and 86% in Nakasongola), however the purpose and goals of these groups differ as does the local dynamics between members. We heard examples were limited group resources (e.g. one ripper) lead to the monopolization of that resource by a few households. Alternatively, there were also many examples where group membership led to benefits for all households and improved access to inputs or other services.

There are a several commercial input suppliers for seed, fertiliser, pesticides, and machinery (e.g. Syova Seed Uganda, FICA Seeds Uganda, Grain Pulse, NASECO, China North Machine Company) however most are in Kampala or larger centres. Input dealers closer to famers are small businesses operating (sometimes selling only 20 units of 1L bottles of herbicides) in small town centres who may purchase supplies from the larger aggregators. There were questions raised about the role of the input suppliers in supporting the adoption of CA. There is a larger issue of adulteration of inputs and the insufficient implementation of existing policies to reduce this practice by input suppliers. Engaging the input suppliers in a manner that is beneficial to them and to farming communities is a key challenge for CA.

RQ3. Where do stakeholders see opportunities for greater/more appropriate crop-livestock interactions in their farming systems?

At a national level the Ugandan government has set some ambitious targets to transform the agriculture sector from subsistence farming to commercial agriculture (this was outlined in the Uganda Vision 2040 document). They have identified investment in irrigation schemes in the country, continued investment in research for improved seeds, and livestock breeds, and investment in the development of the phosphates industry to reduce the cost of fertiliser. The government will work on reforming the extension system, reversing land fragmentation to facilitate mechanization, collect agricultural statistics, improve weather information dissemination, and intensify measures to halt the decline in soil fertility. All these initiatives could facilitate CA adoption and help to overcome some of the challenges identified above. During our stakeholder workshop in Kampala and the qualitative interviews with stakeholders we identified several activities relevant to CA adoption that are already occurring (Table 7).

Table 7. Current and ongoing activities that may be relevant to CA adoption. See acronym table for more details.

Policy	• Through projects like Climate Smart Agriculture and Sustainable Land Management, CA practices have and are being promoted. • Development of the country-level Climate Smart Agriculture policy. • MAAIF is in the process of reviewing and updating the frameworks to make them more inclusive. • There is a move to improve intersectoral linkages among key stakeholders (MAAIF, UNBS, Police, and URA). • Uganda Soils Policy (addressing ISFM).
Research	• Partnering with organizations passionate about CA, starting with local governments and other development agencies.
Farmer practices	• Investing in technologies that are within reach e.g. using local waste materials to make compost. • Promoting Farmer Managed Natural Regeneration (FMNR) in coffee: farmers have been discouraged from adding fertiliser on old coffee trees but instead they are being encouraged to undertake FMNR with fertiliser to enhance coffee productivity. • Training and sensitization of farmers on the benefits of ground cover, through field extension workers at the district. • MAAIF has put in place sensitisation programs for farmers to stop bush burning; and encouraging farmers to mulch for soil and water conservation through field extension workers.
Private sector and value chain	• Government is now taking the lead to engage the private sector actors to increase their participation in CA promotion. • SACCOs can provide credit for input purchase.

In both Lira and Nakasongola, farmers keep livestock that include cattle, goats, pigs, sheep, and poultry. In the previous season of 2022, cattle, goats, pig and poultry constituted 36% of livestock in Lira and 52% in Nakasongola. Livestock production characteristics in both Lira and Nakasongola were rather uniform with no significant differences between districts and between male and female respondents. Shortage of food/feed and water for livestock was considered a challenge for farmers in both regions, with the risk of prolonged droughts also exacerbating this issue (Table 5). Despite these challenges, there were examples where farmers had successfully integrated crop and livestock production. Farmers reporting selling animals during emergencies or crop failures due to drought and this diversification ensured they had funds to buy food and pay school fees. Most of the respondents to our surveys identified themselves as "Integrated Farmers" who adopt a holistic approach to agriculture, combining both crop and livestock production.

If we consider specifically the further integration of crops and livestock on farms future opportunities exist in a few key areas (mainly derived from Appendix 2):

- Better use of manures and understanding the link between manure use and soil fertility for crop production, recognising the role of labour constraints.
- Better use of mulches and crop residues for ground cover and livestock grazing. Finding a solution to overcome contexts where there is competition for mulches and residues, and the high labour demands this entails. Noting that some farmers from our survey were already achieving this to some degree and have practices that could be used by others.
- Strategic use of land area to create grazing for livestock and high production cropping systems. Mechanisation will be key to this strategy.
- Understanding the use of manual labour on the farm for livestock husbandry versus crop production. Using this understanding to identify win-win scenarios for labour use.
- Foresight and testing of packages of technologies and practices that diversify livelihoods sources in crop-livestock farming systems, especially for farmers who are land-constrained (have small areas of land to manage).

Other opportunities identified in the surveys

Subsidized Inputs and market limitations

Economic subsidies on the cost of inputs are frequently seen to address the primary barrier to CA adoption, cost. Subsidizing inputs like improved seeds, herbicides, and machines is crucial to make these essential components of CA more affordable for farmers. This approach directly tackles the financial challenges associated with CA adoption.

"More agricultural support is needed in terms of subsidizing the cost of improved seeds because now a kilogram of maize seeds costs 23,000 UGX which is expensive to some farmers (IDI, Female, Nakasongola)".

The need for quality herbicides is highlighted in several responses. Ensuring the availability of genuine, high-quality herbicides is vital in preventing counterfeit products and assuring farmers of the effectiveness and safety of the chemicals they use in CA practices.

"More agro input outlets should be established in different centres to ease on the access of quality herbicides, seeds and fertilisers (IDI, Male, Lira)."

For example, there were no agro-input outlets in rural areas in Aromo sub-country in Lira district and the only place to buy inputs was Lira city, which is very distant (over 30 km away). Developing supply chain outlets for easy access by farmers would have a large impact. Farmers groups could also play a role in procuring supplies.

Liquid fertiliser

Some farmers feel research and innovation on fertigation is needed for proper application of fertiliser and irrigation system to ensure soil and water conservation for proper plant growth.

Post-harvest handling

Developing proper post handling practices like the warehouse receipt system is seen as best way to improve quality and marketability of produce. Lower quality produce often fetches lower prices and may deter aggregators from purchasing from the same farmers again.

''Farmers without proper storage facilities may be forced to sell their produce early to avoid spoilage, which can limit their ability to wait for premium prices. Pests also attack in the stores and there is exploitation by the millers because of lack of proper storage (IDI, Female, Lira)."

"Lack of good storage facilities so they are forced to sell off early (IDI, Female, Nakasongola)"

Marketing strategies

Respondents highlighted the need to develop various strategies and conditions that can lead to obtaining premium prices for the sale of agricultural produce based on timing, market dynamics, and the quality of the produce. Provision of accurate and reliable market information is needed.

"*By storing the produce until December as that is when the prices are high because there is less stock on the market (IDI, Male, Lira).*"

"Hoarding the produce until when most of the farmers have sold off their produce is good strategy, selling produce when schools are opening because within that period, most of the schools stock food to take them through the whole term (IDI, Female, Nakasongola)."

"In the second season from December to May, the supply is low and the demand is high as most farmers might have planted but not yet harvested yet there are those who had stored and having what to sell (IDI, Female, Nakasongola)."

Financial Support and Credit Facilities

Access to financial support, including credit facilities or microloans, is repeatedly seen as an opportunity to address the financial constraints that deter farmers from adopting CA. Financial assistance can make it more feasible for farmers to invest in the machinery and inputs required for CA.

"Accessing loans by the farmers should be made easy to enable them purchase the inputs and these inputs should also be subsidized (IDI, Male, Nakasongola)."

Training and capacity building

Farmers emphasized the need for training, and capacity building in CA as essential for equipping farmers with the knowledge and skills required for successful CA practices. Continuous training and support through extension workers is also crucial in helping farmers implement CA techniques effectively.

"Intensify training and make farmers aware of the climatic change and the benefits of practicing CA inputs and equipment should be made accessible (IDI, Male, Lira).

Consistently training the farmers on the benefits as farmers don't adopt at the same rate (IDI, Male, Lira)."

"Farmers should form groups and engage in collective agricultural trainings to enable them understand the new modern agricultural technologies (IDI, Male, Lira)."

Demonstration Farms

The idea of establishing demonstration farms (plots or sites within farms) is frequently mentioned. These farms serve as practical examples of successful CA adoption, allowing farmers to witness the benefits firsthand and gain inspiration and knowledge from observing working CA systems.

"Demonstrations sites should be set in order to motivate farmers (IDI, Male, Lira)."

"More agricultural trainings and demonstration gardens in villages are needed to help farmers recreate (IDI, Female, Nakasongola)."

"Promote farmer to farmer learning through demonstrations and exchange visits (IDI, Male, Nakasongola)."

Community and Peer Learning

Developing knowledge sharing platforms among farmers to enhance community-based and peer-to-peer learning is often cited as an effective strategy. This approach leverages the experiences of successful CA practitioners to mentor and guide others in adopting CA practices.

"Sensitizing the community about the CA practices because change of mindset is not easy there is a need for demonstration shows to enable farmers take CA practices up (IDI, Male, Lira)."

Next steps in this area

Non-farm qualitative structured interviews

Through the qualitative survey of non-farm stakeholders, we generated insights into the challenges and opportunities seen by people in the innovation system (Appendix 2) and the higher-level opportunities and gaps (Appendix 2) they see given their experience and knowledge. To summarise there were common themes around:

1. The need to refine and test packages of practices or technologies that are locally relevant and could lead to system change.
2. Diversification of cropping systems for diversified income sources and improved food security.
3. Improving the effectiveness and efficiency of value chains, especially for small-holder farmers.
4. Incentives and investment models to address long-term sustainability challenges like declining soil fertility.
5. The challenge presented by the magnitude of extension and communication needed to reach all farmers, given the limited number of staff focussed on this task today.

Despite the challenges the outlook for the future given by the participants was hopeful. They identified shifts in government policy and directives that could lead to change, development agencies who support farmers, and a high degree of knowledge about how their systems operate in a bio-physical sense.

Kampala stakeholder workshop

A workshop was held in Kampala on the 22nd November 2023 with key stakeholders (Fig. 9). The participants were asked to work in small groups to identify activities they considered high priority to be addressed in the next five years. Some of these require more discussion around the details, but we asked participants to simply sketch out important activities based on the challenges discussed prior. Key activities in the next 5 years identified were:

Famers

1. Support for replacement of ox-drawn rippers with 2W walking tractors with ripper attachment and 4W tractors with attachments.
2. Support for irrigation systems development.
3. Support for post-harvest handling (stores, shellers, grain mill, PICS bags) to help farmers to sell when the price is high and create added value to raw products.
4. More frequent training and monitoring for capacity development. This could include exchange visits and more frequent interactions with extension workers.
5. Improved regulation of input dealers' practices. Advice given when selling seeds, pesticides, and fertilisers. Input sellers currently don't have the knowledge on CA practices and the inputs they are selling to provide advice.
6. Enable a mindset change by farmers on the use of herbicides, pesticides, and fertilisers (sensitization needed). Explaining to farmers the importance of the use of residues rather than burning them is needed.

Policy

1. There is already a certification and testing requirement for all businesses selling inputs (seeds, fertilisers, and pesticides), however adulteration of products was commonly reported. Enforcement of this policy remains challenging. The group proposed a higher-standard certification scheme for a targeted group of input suppliers (perhaps partnered with leading CA farmers) to ensure that quality inputs and advice on CA practices were provided. The input supplier receiving the "CA++" stamp would have undergone additional training and professional development, be compliant with standards and testing, and be providing quality assurance to customers looking for products important for CA practices. The incentives needed for an individual to undertake this certification still need to be determined.

2. A research project to address the question: How can we strengthen implementation of the existing policies around quality input supply and reduce the practice of adulteration of inputs?
    a. Assess what is happening in other countries/regions as this is not a problem only faced by Uganda.
    b. Identify technologies in labelling, anti-tampering packaging, tracking, and tracing of products that may help address this problem.
    c. Conduct capacity building activities for extension and policy staff.
    d. Develop recommendations for how the implementation of the existing policy could be improved.
3. Enable and support the completion of the policy on the country program for Climate Smart Agriculture (CSA). This policy will provide a framework to guide donor activities in relation to CA, enable access to new machinery relevant to CA, and help to make sure machinery is used to support adoption of CA practices (versus other practices). This country program is well developed but has had delays to being endorsed (due to COVID-19 pandemic).
4. Capacity building at multiple levels to enhance the understanding of the benefits of CA to farmers, communities, and the nation. Using public, private partnerships (PPPs). [also mentioned in extension below]

Extension

1. Capacity development for
    a. Extension workers and policymakers, cultural and community leaders
    b. CA groups and leader farmers

    This would include standardization of the CA training materials and the use of community-based facilitators (through PPPs).

2. The development of vibrant documentation
    a. Improved data collection and management
    b. Recording and communication of success stories and failures
    c. Improved reporting
3. Enable the scaling out and up of CA practices and innovations
    a. Demonstrations and field days expanded.
    b. Exchange visits and organisation competitions

Research

1. Adapt CA Research to Local Context: Ensure that research activities are context-specific and consider the diverse agroecological zones in Uganda. Tailor conservation farming practices to the specific needs and conditions of different regions. Research objectives could include but not limited to:
    a. Making recommendations for the different CA packages
    b. Testing business models to effectively link farmers to markets and input dealers to farmers.
    c. Involvement of value chain actors at all levels of the different products including postharvest handling.
2. Demonstration Farms (plots or sites within farms): Establish demonstration farms to showcase the benefits of conservation farming. Farmers are more likely to adopt practices they can see in action and observe the positive outcomes. Research objectives could include but not limited to:
    a. Urban farming practices for crop intensification (mulching utilization or absence of)
    b. Backyard gardens-Kitchen gardens
    c. Participatory promotion and dissemination of proven technologies (fertilisers, herbicide, seeds, drudgery reduction equipment, machines etc.)
3. Research on Livestock Integration: Conduct research on effective integration of livestock into conservation farming systems. Address concerns related to livestock management within conservation agriculture, exploring how livestock can complement and enhance soil health. Research objectives could include but not limited to:

    a. Promote natural resource management
    b. Promoting sustainable land use and management practices
4. Crop-Livestock Systems Studies: Investigate integrated crop-livestock systems to demonstrate the synergy between livestock and conservation farming. This could include:
    a. Studies on rotational grazing
    b. cover cropping
    c. manure management
5. Farmers' Participation in Research: Involve farmers in the research process. Their practical knowledge can contribute to more effective and locally relevant conservation farming practices. Research objectives could include but not limited to:
    - Indigenous Technical Knowledge
6. Integrated weed management: This will involve identifying weed management options that involve less of chemical usage.

Presentation summary: *Lessons on translating evidence to impact in soil health systems in Africa*, Paswel Marenya and Jonathan Odhong (CIMMYT)

- Immediate benefits (agronomic and financial) are an irreducible minimum for adoption.
- Invest in dense networks of farmer learning sites. A minimum of 6-8 seasons of demonstrations appears needed to generate scaling momentum (Khainga et al. 2021).
- Invest in re-skilling extension in digital: reduce the research-adoption cycles. It takes up to 3 years for farmers to adopt a new maize variety.
- Social innovations are indispensable.
- Scale up proven scaling methods not just technologies or practices.
- Scale know-how and capacity before emphasizing specific practices.

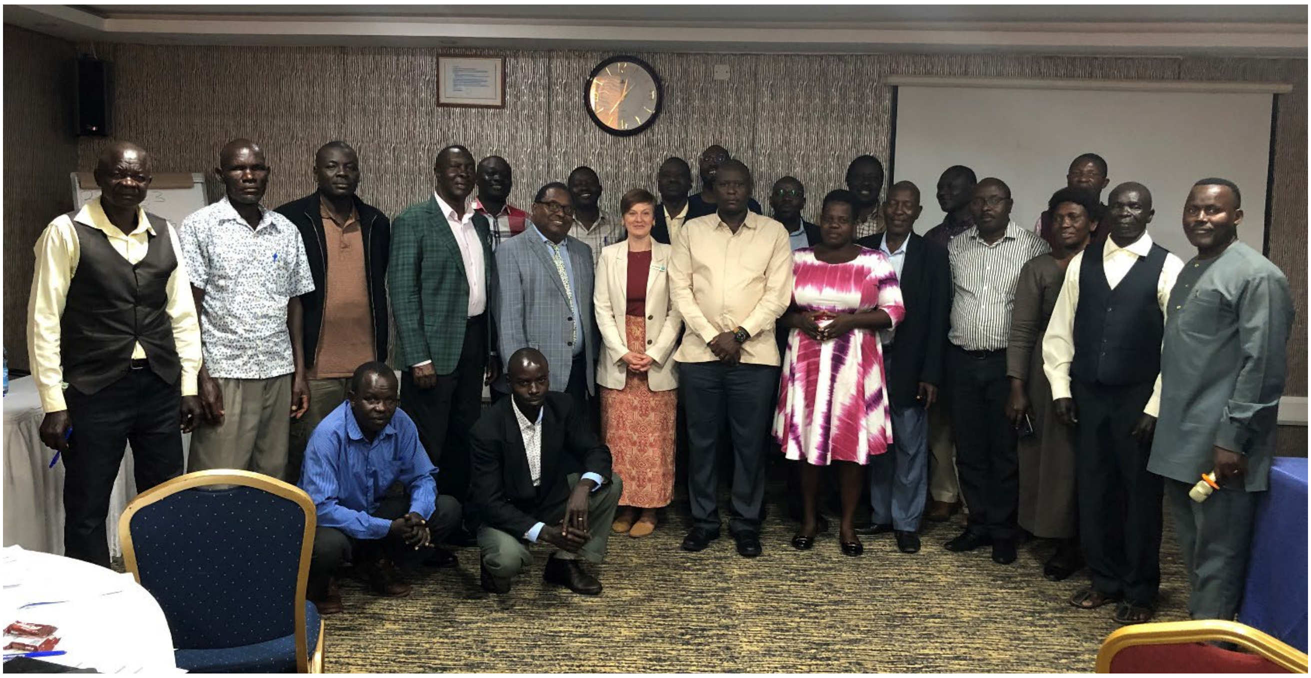

Fig 9. Stakeholder workshop, Kampala 22nd November 2023. Adoption of Conservation Agriculture farming practices in Uganda: Charting a way forward.

8 Impacts

8.1 Scientific impacts – now and in 5 years

This project provided an opportunity for the stakeholders in Uganda who had been part of the SIMLESA project to come together and reflect on what had been achieved and what still needs to be done in the future. Through our interviews with other stakeholders in Australia we have also highlighted the scientific achievements of past projects and identified research investments that will lead to impact in the future. We will summarize this report into a fact sheet for stakeholders and ideally develop the primary data collected in an opinion article over the next six months. We are not presenting any revolutionary scientific findings but can provide a synthesis of what needs to happen in the next 5 years that may be useful for policymakers, funders, and development organisations.

8.2 Capacity impacts – now and in 5 years

This project involved us gathering opinions from scientists, policymakers, district extension staff, input suppliers and farmers. We asked both Australian and Ugandan organisations to continue to operate in this area over the next five years. The historical network developed under SIMLESA still exists and is a useful communication tool. Many organisations are seeing key staff members retire however, many were positive about the future junior and mid-career staff in their organisations to take on future challenging projects.

This project team was led by CSIRO and senior scientists in Uganda but supported by local staff at NARI (technical officers and drivers), people at the Makerere University and independent local consultants using various employment arrangements. Most of the discussion was via online meetings and whilst we would have preferred more in-country time that process worked well for delivery of this project. Overall, we see high capacity for people in Uganda to work effectively using more online tools and resources and this enables different methods for Australian researchers to engage in future projects.

8.3 Community impacts – now and in 5 years

8.3.1 Economic impacts

The direct economic impacts of this short project are minimal as this was a scoping study. However, the larger question about increasing agricultural productivity and its link to household income and food security in Uganda was a continual factor in our discussions about future priorities. The Uganda Vision 2040 predicts a continued shift in movement of the labour force from agriculture to the industry and services sector by 2040. The pressure this will place on food security is unknown but practices to increase agricultural productivity that require less labour will be necessary.

8.3.2 Social impacts

The social impacts of this short project relate to the ability to continue and revitalize some of the informal learning networks developed during SIMLESA. Being able to gather people together at the workshop to assess the current challenges and collectively determine a pathway forward was an important activity that was valued by the participants.

8.3.3 Environmental impacts

The environmental impacts of this project alone are minimal as our goal was to gather information about the challenges faced by farmers and identify the next steps. However, the recommendations we make have potential to improve the sustainability of farming systems in Uganda. Halting and reversing soil fertility declines (and understanding the cause of productivity declines), especially under CA systems, is one of our main conclusions from this research.

8.4 Communication and dissemination activities

The workshop in Kampala was used to communicate with some of the stakeholders. We have also circulated early drafts of this report to certain stakeholders. We will develop the report (once approved by ACIAR) into a simple fact sheet that can be shared with stakeholder and would like to write a more detailed scientific paper over the next 6 months.

9 Conclusions and recommendations

9.1 Conclusions

Much has been achieved over the previous 10 years in terms of increased awareness of the potential benefits of adoption of CA practices in several institutions. There are some leading farmers taking up some CA practices and realizing benefits and in the two districts we focussed on, over half of farmers have used CA practices in some way for four seasons (Fig. 10). Some of the CA practices are part of traditional farming practices and well aligned with the current farming system. Others are challenging to adopt for a diversity of reasons. If we assume it takes three years to test and adopt certain practices, many farmers are well along the transition pathway to CA adoption at significant scales. However, there is also frustrations due to the lack of quality inputs, capacity to train many farmers, and dis-adoption of certain practices. SIMLESA and related activities have built a strong foundation for further scale out of practices in Uganda but scale up at the same time is necessary to overcome some of the input supply and mechanisation challenges (which can't be addressed by focussing only on the farm-level).

The challenges to improving agricultural productivity identified in our study are many and include lack of access to quality inputs, cost of inputs, access to machinery, agripest management for crops and livestock, lack of water, shortage of land, affordability of post-harvest storage facilities, access to markets to sell produce at a high price, and farm labour issues. No single project or investment can address all these challenges at once however there are clear drivers for change at local, regional, national, and international levels. The enthusiasm for Climate Smart Agriculture and the need to adopt sustainable agricultural practices all support a greater emphasis on CA adoption, and continued use of CA practices in areas where progress has already been made. Projects specifically designed to support and further catalyse the drivers for change already occurring in Uganda would be ideal (Fig. 10).

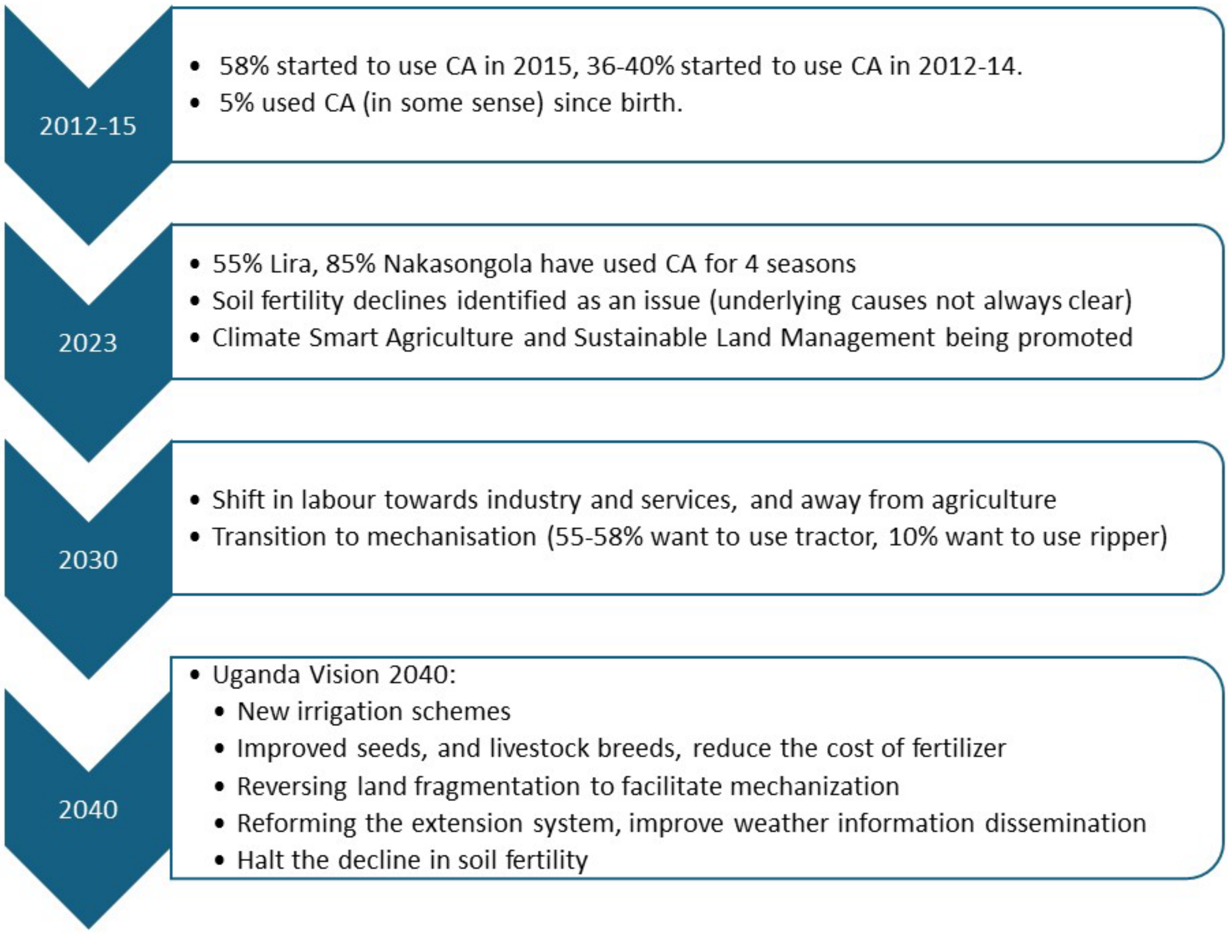

Fig. 10. A summary of some of the key milestones observed in our study historically, currently, and planned in the future. Some of these factors are drivers for change that facilitate the greater adoption of CA practices.

To summarize our conclusions from this short scoping study are:

Determine how to address the short-term costs of adoption of CA practices.

The additional costs borne by the farmers reflect the financial challenges that they face when transitioning to CA practices. Managing these costs while maximizing the benefits of CA, such as improved soil health, increased yields, and reduced environmental impact, is a crucial aspect of successful adoption (also see Brown et al. 2020). Farmers may seek support and strategies to offset these expenses effectively. Our study showed that farmers use their own resources and support from subsidies and NGOs to test and adopt certain practices.

Understanding the causes of reported declines in soil fertility under existing CA systems as a high priority.

Understanding the causes and addressing the problem of soil fertility declines (and/or yield declines) on farms using CA practices would enable the benefits of this system to be realized and support sustained adoption. Proper crop-livestock integration is a useful tool for addressing some soil fertility declines (using organic and inorganic fertilisers, residue and mulch management, and ground cover management). Addressing this underlying challenge will also enable more farmers to successfully intercrop and intensify crop production practices. It will enable farmers to use CA practices on larger areas of their land, reduce the risk of dis-adoption, and perhaps demonstrate benefits to other farmers.

Support capacity to modify practices to local needs and economic realities.

Appropriate mechanisation (be that a ripper, 2W tractor, 4W tractor or direct Seeders) is going to be a key part in the transition to CA (and with the transition to lower labour availability for agriculture in general). We need to explore service delivery mechanisms to support access to machinery. Investment in the support systems needed for people to be able to modify the machines and the use of the machines in their households. This includes local manufacturers and repairers who can adapt machinery for a variety of uses. We can see from our surveys that farmers can adapt and modify CA practices to better suit their needs, but not all farmers have the capacity to do so. Extension systems must be built to encourage and support and enable modification and experience-based learning, rather than disseminating packages of practices with rigid methods.

Innovation Platforms are useful for enabling CA adoption, but we need to allow them to change, grow, dis-band and evolve through time after a project is complete.

In Uganda we saw how farmer groups evolved into Innovation Platforms through support provided during SIMLESA. Many were started during the project and two have continued until today due to tangible benefits to the participants. Limited project funds were used to establish the groups and to conduct regular visits to get the groups organized and collaborating. These two remaining groups are currently evolving and operating with limited input from others and serving a clear purpose for their farmers and communities. Below we recommend future investment in Innovation Platforms, but we need to set realistic expectations about longevity after a project is complete and allow them to change to deliver benefits to participants. Integrating Innovation Platforms with demonstration sites and farmer knowledge exchanges means their influence extends beyond the immediate participants and can be hard to measure.

9.2 Recommendations

The research team was impressed with the degree of uptake of certain CA practices and the degree of awareness of CA practices in the regions and at the various policy levels (some of this awareness can be linked back to SIMLESA and aligned projects and extends from some traditional practices). There was some integration of crop and livestock assets/practices on the farms in the two districts, but a growing realization that integration may be needed for the sustained adoption of CA across time. There is an opportunity to capitalize on the momentum around the Climate Smart Agriculture concept and its use as a driver for change in agricultural landscapes. The focus of future research could shift in two divergent streams:

1. Methods to scale-out the adoption of CA practices in new regions with appropriate agroecologies:
    a. Modelling and *ex ante* assessment at national levels using the adopt tool or similar approach to map the areas of potential benefit for certain practices. Noting that a package of practices in a region with a dense network of farmer support has shown success in the past. A foresighting step is also required in the context of climate change.
    b. Upscaling the Innovation Platform approach and expanding to new regions to develop farmer networks to support CA adoption.
    c. Research on the initial short-term economic and resource costs of CA practice adoption and how to incentivise or buffer against these costs without providing economic subsidies.
    d. Working with national and regional policy initiatives (and development partners) to scale-up CA practices and supports to encourage adoption. Better knowledge and integration with livestock development policies to improve production.
2. Research to improve the sustained adoption of CA practices in farming communities long-term:
    a. Research to understand the causes of, and reverse, soil fertility declines in CA systems, circularity of nutrients in small-holder systems and use of organic manure and inorganic fertilisers. Especially focussed on climate change and increased risk of drought (therefore requires field studies as well as foresighting and modelling).

b. Greater understanding about how to integrate livestock at the farm-level in CA systems through the movement and use of manures and mulches. Again, foresighting should play a role here. The use of free grazing and differences in land ownership between regions needs to be included in this analysis.
c. Research on durable and cost-effective weed and disease management in CA systems. Our farmer surveys continually identified pest and disease management challenges (for both crops and livestock) beyond weeds, but this was seen as the most critical group for CA adoption, and there is a gap in capacity in this research area. Disease and other pest management for both crops and livestock is an area of concern.
d. The use of newly developed Innovation Platforms to enable access to high quality inputs (seeds, fertilisers, pesticides). Essentially bringing rural input suppliers into the IPs to learn about CA and develop incentives for them to supply high quality inputs for certain practices.
e. Working with national and regional governments to support transition to appropriate mechanisation. This could involve demonstrations of a variety of machinery in CA systems and working to develop sustainable business models (including service provision models) for CA systems. The training and development of local manufacturers and repairers of farm machinery could also aid in the modification of machinery to suit local conditions and needs. Learnings from the FACASI project would be useful here.

The former stream (1) is focussed on bringing greater awareness of CA practices to new regions, and the latter (2) working in communities who already have some practice change occurring, but new challenges will impact sustained adoption. Both could include the use of demonstration farms, case studies and development and dissemination of newly developed communication tools. Participatory research designed with, and tested by, farmers and farming communities (and involving active participation by both women and men) was seen as critical to success in both streams.

Whilst we have focussed on Uganda in this scoping study the two streams above may also apply and be relevant to other countries in East Africa.

Recommendations for ACIAR

- Whilst the two streams above are not mutually exclusive, we suggest ACIAR focusses efforts on stream 2 as this has larger research requirements. Furthermore, using a project focussed on 2 to catalyse other initiatives (at regional and national levels) focussed on 1 would be ideal. Determining if these issues are also relevant for other countries in East Africa would be useful as this could facilitate the use of Uganda a key country to extend learnings and interventions to other relevant countries.

- Use the community of practice and network of scientists and organisations built during SIMLESA to deliver the work identified above. Through this process we have spoken with early-, mid-, and late-career scientists and extension staff in organizations in Australia and Uganda. When asked they were enthusiastic and willing to consider future research in this area and if given the opportunity could deliver as a multi-disciplinary team.

Recommendations for Ugandan organisations

- Capacity-building is an ongoing need for all members of the agriculture innovation system. Whilst we have a good understanding of what farmers need to build capacity, we have spent less time on what input suppliers, people in the value chain, extension workers, policymakers and scientists need to build capacity to enable adoption of CA practices on farm. We recommend targeted capacity building activities are developed, identified through a process to focus on certain areas of the innovation system. The community of practice already established for CA could assist in this work.

- Quality input supply and machinery supply for CA systems is significantly constraining the ability of Ugandan farmers to innovate and change practices. We need to consider a range of service models and service providers including a dissemination model for ownership and service provision. The private sector needs to be leaders in this shift and recognize opportunities for them over the next two decades (through public private partnerships models). We recommend the use of case studies on how local supply could be achieved, based on research recommendations from the activities above. We have capacity in the regions for agricultural machinery fabrication, but we need to determine incentives and business models that are equitable and profitable.

- Many stakeholders noted the challenge of farmers having adequate time with suitably trained field extension workers. In some areas the ratios are low, or the extension worker does not have resources to travel or does not have the appropriate knowledge for the practice change being considered. The focus of the extension services provided by NGOs and those provided by the government should be aligned and co-ordinated.

Recommendations for Australian research organisations

- The challenges faced by the farmers we spoke to in Uganda are not unique and many of the scientific tools, analysis approaches, and mapping and measurement techniques used in other contexts (including Australia) could be useful here.

- In Australian systems the long-term adoption of CA over large areas of rainfed grain production systems has led to benefits but also new challenges in terms of the management of herbicide resistant weeds (D'Emden et al. 2006). Transferring some of those learnings into Ugandan systems where herbicide use is still in its infancy is worth considering and may prevent Ugandan farmers seeing the same problems in the future in their systems.

- CSIRO scientists (in collaboration with other research partners) have a long history in the analysis and risk management in CA farming systems. We have a range of tools like APSIM, CLEM, and Smallholder ADOPT that have been developed over many projects. The Value-Ag framework that combines farm economics and risk, adoption and impact and has been applied to CA case studies in SE Asia and Mexico. We have a history of working on collaborative projects with local partners and other Australian institutions (UQ has a strong track record in this area) to improve sustainable farming practices in small-holder contexts.

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11 Appendixes

Appendix 1. Survey tools and additional details from the survey results

Additional analyses of the survey results can be found on the CSIRO data access portal. This record is closed but you can seek permission to view the files by contacting sarina.macfadyen@csiro.au.

Data collection record:

Macfadyen, Sarina; Kalyebi, Andrew; Mubiru, Drake; Hulthen, Andy (2024): Adoption of conservation agriculture practices in selected sites in Uganda: drivers, constraints, and obstacles. v3. CSIRO. Data Collection. csiro:61403

https://data.csiro.au/collection/csiro:61403

This data collection includes:

- Templates of the survey tools (as PDF and XLS files)
- Demographics of the survey respondents and a summary of the qualitative responses.
- Summary of the responses by district (with statistical results).
- Summary of the responses by gender (with statistical results).
- Some photos showing the different methods used by farmers.

Appendix 2. Summary tables from non-farm stakeholders qualitative interviews

Table A2.1. Summary of the responses from different stakeholder groups via the structured interviews. Respondents were asked to select a practice area to focus the conversation (see Appendix 1 for survey templates).

Practice	Benefits of this practice	Challenges of this practice	Opportunities
Conservation Agriculture overall	Helps with the labour and livestock issues.	Minimising tillage needs small scale machinery technologies (not yet available and feasible). Alternatives to crop residues needed.	Diverse agroecology therefore easy to promote once well designed.
Crop-livestock Interactions	Improved soil health leading to improved crop productivity and thus on farm incomes. Integration of crops with livestock improves food security and nutrition. Minimised wastage of crop wastes and residues since they are used as animal feeds.	Limited knowledge and capacity on manure management. Cutting down of trees/branches in search of animal feeds. Farmers have not adopted keeping improved breeds (local breeds are less productive). Livestock management is relatively expensive for local farmers, and some cannot acquire livestock. Lack of enough land for grazing. Livestock management is complex.	Government livestock re-stocking project. Uganda Soils Policy (addressing Integrated Soil Fertility Management ISFM). Working with networks e.g. Uganda Land care Network (ULN) and Civil Society Organisations e.g. Participatory Ecological Land Use Management (PELUM) Association. There are markets available for both animal and crop products. Can be included in climate smart agriculture projects.
Crop management and intercropping	Economical, management, maintain moisture throughout the season, dry end to season so we can keep moisture later in the season to improve yield.	All cultivars may not work, need different practices for the cultivars and the species, the row spacing etc. The agronomy needs to change for intercropping. Need all the components together.	Africa losing soil fertility and diversity. Need to regenerate the system as well as have an economic benefit.

Input Management	Using improved seed, pesticides and fertiliser, farmers can realise high yields. Increased farmer incomes. Improved varieties are often reliant on inputs to deliver benefits.	Recycling of seed especially the open pollinated varieties (OPVs) leads to systemic yield reduction. Some farmers cannot afford nor access quality inputs. Expectation that these inputs will be provided by others, but they need to be part of farm planning. Adulteration of inputs has disincentivised farmers. Sharing of machinery can lead to incorrect application of products. Limited interaction between technology providers/developers and farmers	There exist several sectors e.g. Ministry of Agriculture Animal Industry and Fisheries (MAAIF), Uganda National Bureau of Standards (UNBS) and Uganda Revenue Authority (URA). Farmers already in groups so can purchase inputs as a collective. Savings and Credit Cooperative Societies (SACCOs) can provide credit for input purchase. There are technical staff in both district and sub-county level and soil testing kits. Many resources that farmers may not be aware of.
Machinery	It saves time in land preparation, making it possible to plant in time. Reduces drudgery. Machines like the ripper only opens where a seed is going to be planted thus minimum soil disturbance which reduces soil erosion.	Mechanization is still rudimentary, focusing mainly on tillage, leaving out other operations. There is need for technology integration to reduce drudgery along the commodity value chains. Private sector not fully engaged yet, accessibility a problem in some areas.	Government has put up policy towards promotional of Agro Industrialisation. Through cooperatives and Savings and Credit Cooperative Societies (SACCOs) there has been improved access to credit for agricultural services and inputs e.g. machinery.
Minimum tillage	Saves labour and leads to timely operation for farmers. Reduces soil erosion. Reduces costs (e.g. weeding). Increases productivity, Permanent Planting Basins (PPB) increase yield. Minimum soil disturbance increases the soil water holding capacity, leading to increased yields. Most of the minimum soil disturbance practices involve one time investments e.g construction of the planting holes and trenches, which thereafter only require minimum maintenance.	The initial development of PPBs practice is labour intensive; digging planting basins in dry season can be very tiresome; this requires employing people to do it which has cost implications. Most farmers lack knowledge and technical know how to Implement the practice (also need a mindset change from traditional approaches). It also involves a lot of measurements making it cumbersome for the farmers. Farmers lack access to machinery and tools needed in establishment of this technology, for example the input shops in the communities do not have small hand hoes and yet they are required in digging the PPBs. There has not been much research on weeds and weed management.	There is some availability of funding opportunities for CA practices. Links to Climate Smart Agriculture (CSA). Government policies are in support of CA practices. Development projects have availed farmers with rippers at local level. Government has started retooling extensions workers with CA skills and knowledge. Farmers are organised in groups where they are encouraged to save; this has established revolving funds from which farmers can borrow for CA.

Mulching	Retention of water in the soil. Practice adds nutrients in the soil and helps with weed control. Used more in perennial crops now than annual crops.	Scarcity of mulching material depending on the area. Competition for mulching materials; ordinarily in CA systems crop residues are used as mulch, however the same residues are required as animal feeds. Mulching materials are eaten by termites or other pests before their benefits are realised. Costly labour involved in getting mulching materials and applying them.	Farmers appreciating the benefits of the practice, therefore once availed with the necessary resources they can easily take on the practice. Farmers in the northern and south-western part of the country have access to mulching material e.g. they collect them from the surrounding swamps.
Rotation	Diversification helps in staggering/reducing risks. Crop rotation helps in the biological control of diseases and pests. Practise helps with soil health improvement thus increasing crop productivity. Because adoption rates are low a lot of the benefits have not been seen yet.	Some commodities are on high demand; therefore, farmers tend to grow them every season with little consideration for crop rotation.	There are several development agencies willing to support farmers in conservation e.g. providing tree seedlings and improved crop varieties. Rotations are already part of the traditional cropping systems; therefore, this makes scaling up and out easy.
Soil health management	The structure of the soils improved leading to yield increases. Below ground habitation increased, and soil biological activities were enhanced. Above ground cover improved and was sustained. Streams that had dried up started flowing again due to recharge.	Farmers were ignorant about the soil improvement technologies that were introduced. Even though there is a Zonal Research Institute, farmers had limited access to the technologies; this was because the institute/farmers were not proactive. Farm labour is a big challenge.	There is an existing researcher farmer interface. There is several CA technologies that help to save time.

Table A2.2. Summary of the responses from different stakeholder groups via the structured interviews. We asked about general opportunities and gaps they see as important (see Appendix 1 for survey templates).

Stakeholder	Opportunities	Gaps
Policy makers	Policy frameworks: Fertiliser Policy (both organic and inorganic). Long Term Strategy for addressing greenhouse gas emissions from animals. Convention on Biodiversity (CBD) integrated farming systems. Because of climate change, government and development partners are in support of CA practices. We are building on the traditional systems of conservation for example intercropping.	Weak coordination among Ministries, Departments and Agencies (MDAs); this is the case even when some of the issues are cross cutting e.g. soils. Expired frameworks, some of which were not very inclusive. Mindset: some politicians think that the Uganda soils are fertile, and some communities also think that their soils are fertile, basing just on outlook. Resources: a lot is put in the budget but very little in actual allocations.

		Research and Innovation gaps. Insufficient data to support CA promotions. Mulch is becoming scarce. Limited knowledge to implement mulch use practices. Some farmers do not know that mulching works on annuals. Some farmers do not know the benefits. Most project are short term; therefore, farmer follow up is minimal leading to low sustainability. Low ratio of Field Extension Workers (FEW) to farmers. Wide area of coverage. Some FEWs are not holistic in approach e.g. veterinarians find it difficult to advise farmers on crop management. Weak private sector not oriented towards CA in terms of provision of inputs and services. There is a lot of bush burning, especially in northern Uganda.
Network leads	There is a global push towards conservation. There are government development programs intended to empower farmers with financial independence e.g. the Parish Development Model (PDM); through this program farmers are directly given money to procure agricultural inputs of their choice.	Many CA players do it by default; there is inadequate capacity building programs. There are many unprofessional dealers. Low literacy levels limit interventions. Land fragmentation limit agricultural production. Project duration is limited. Linkages between farms and markets are weak. Youthful farmers have their own understanding and concerns. Some produce has very limited shelf life (highly perishable) e.g. tomatoes, carrots and Irish potatoes.
Sustainable Land Management Specialist	CA has been mainstreamed in the Agriculture Sector Development Plan and the National Development Plan. There is a National Agricultural Extension Policy and a strategy to operationalise the policy. The Diary Development Authority has developed mechanisms to support milk export. Schools offer a learning environment; therefore pupils/students can be skilled easily. The sheer numbers of pupils/students help in scaling up and out of CA.	Follow-up by government agencies is limited. High cost of local participation (farmer to farmer visits are less; high cost of exchange visits). However, farmers need to be more involved because they are the implementers. CA information from promoting projects usually ends at extension workers level, leaving farmers out and yet they are the key people. Field extension workers are not properly trained/equipped to disseminate and impart knowledge on CA. Farmers are not leading nor owning the CA experience thus limiting sustainability.
Researchers	Formal and informal institutions and redesign, model farmers, best practice farmers demonstrate practices to other farmers, extension service common across different areas (specialized for a combination of practices), maybe even private run. Residue from previous year crop for animal feed, providing alternative inputs for livestock (e.g. subsidy), financial credit for farmers to access inputs, input markets very limited (e.g. fodder market for livestock).	Understand from farmers themselves, reflect on their experience, revisiting the failure to adopt especially the intercropping (low adoption rate). Understanding the problem/context. CA different in different environments, need to design to each context. Need to train experts to tackle these issues/problems. Government has not embraced CA wholly, for examples tractors provided by MAAIF to the districts do not favour CA. Policies and bylaws are not fully entrenched in communities to guide farmers to conserve their land for posterity. Linkages between government and the private

		sector are weak. Policies are not popularised; dissemination of policies is still very weak.